GEOPHYSICS

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Physics and Geophysics	*Editorial*	1
Physics in America and the AIP	*P. E. Klopsteg*	2
Least Squares for Seismic Interpretation	*Scheidegger and Willmore*	9
Velocity Variations with Press. and Temp.	*Hughes and Maurette*	23
Seismic Exploration for Ancient Channels	*Pakiser and Black*	32
Regional Gravity Survey in Utah	*Johnson and Cook*	48
California Gravity Maximum Due to Isostatic Effect	*L. F. Ivanhoe*	62
Guard Electrode Response Curves	*de Witte, Fournier, and Tejada-Flores*	67
Transient Electromagnetic Waves in Conducting Medium	*Bhattacharyya*	75
Geophysical Activity in 1955	*H. G. Patrick*	89
Geophysical Activity in 1956: Interim Report	*H. G. Patrick*	104
Index of Wells Shot for Velocity—Fifth Supplement	*V. U. Gaither*	120

DEPARTMENTS

Patents		136
Reviews		147
Discussions and Communications		
Letter to the Editor		154
Memorials		
Charles Harry Carlisle	*J. Angelo Smith*	155
Carl A. Heiland	*John C. Hollister*	157
James Bernard Macelwane	*Victor J. Blum*	159
Morris Miller Slotnick	*R. R. Thompson*	163
Contributors		165
Society Round Table		
Committees		171
Local Sections		172
Membership Applications Received		176
Meetings		177
Annual Report		180
Announcements		214
Personal Items		221
Calendar of Meetings		224

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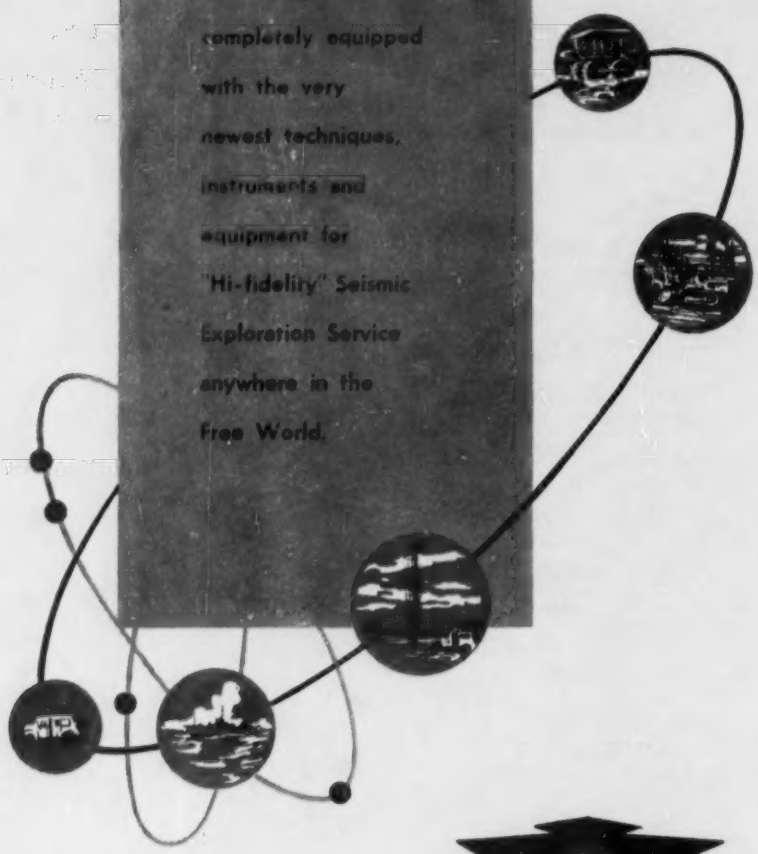

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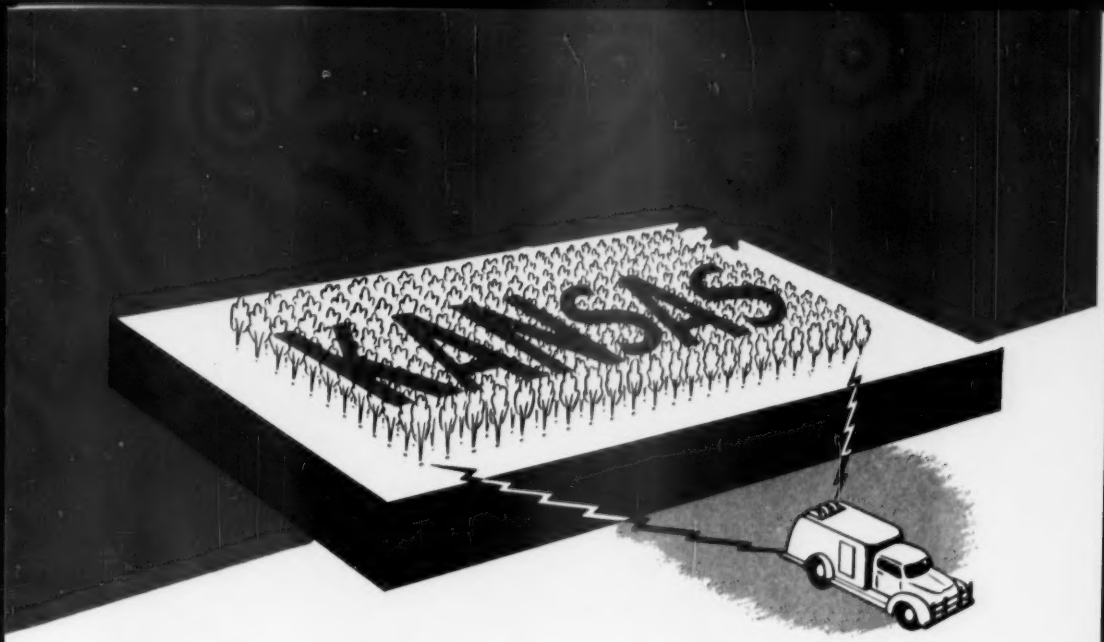

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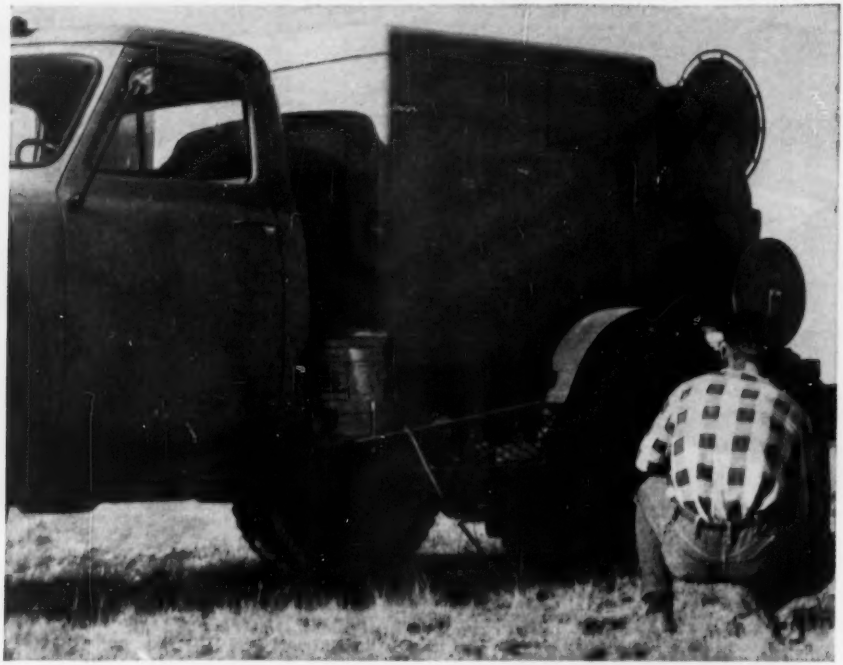

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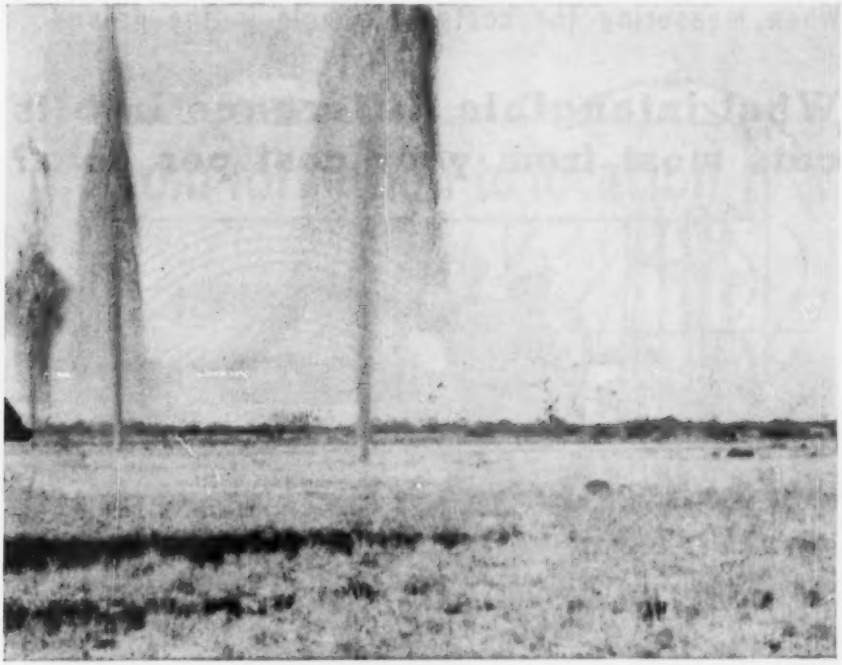

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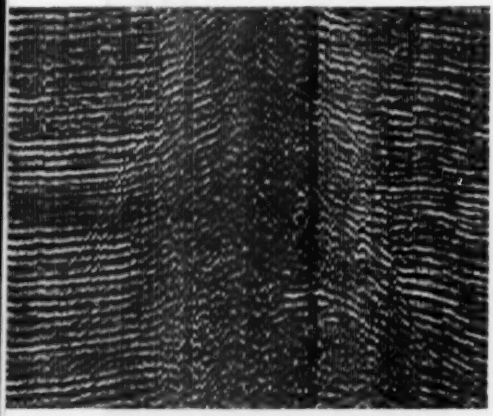

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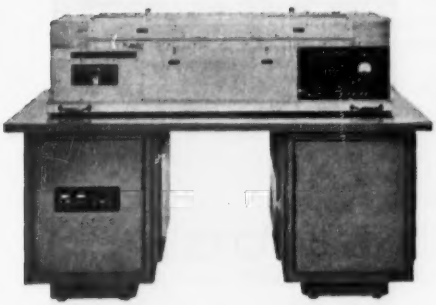

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Century Geophysical Corp. 5
Continental Geophysical Co. 63
Custom Fabrication Corp. 10

Decca Navigation Co., Ltd. 36
DuPont—Explosives 6-7

EAEG 34
Eastman Kodak Co. 25
Economic Geology 26
Elder Trailer & Body, Inc. 32
Electrodynamic Instrument Corp. 42
Electro-Tech International 52
Electro-Tech Labs 14, 15, 56, 72

Fairchild Aerial Surveys 62

General Geophysical Co. 31
Geophysical Service, Inc. ..... Cover IV
Geophysical Society of Tulsa 32
GMX Corporation 59
Gravity Meter Exploration Co. ..... Insert following page 16
Griffin Tank & Welding Svc. ..... Insert between pages 32-33

Harrison Equipment Co. 68
Hercules Powder Co. 60
Houston Technical Labs. ..... Insert between pages 40-41

Independent Exploration Co. 67

Kern Instrument Co. 46
Klaus Exploration Co. 41
Koenig Iron Works 29

Lane-Wells Co. 49

Mayes-Bevan Co. 39
Mayhew Supply Co. ..... Insert between pages 32-33
E. V. McCollum & Co. 61
McCollum Exploration Co. 43
Mid-Continent Geophysical Co. 45
Mission Mfg. Co. ..... Insert following page 16
Mount Sopris Instrument Corp. 66

National Geophysical Co. ..... Cover II
North American Geoph. Co. 54

Oklahoma Geophysical Co. 9

Petroleum Geophysical Co. 64
Petroleum Helicopters, Inc. 75
Petty Geophysical Engineering Co. 73
Prakla 35

Robert H. Ray Co. 55
Rayflex Exploration Co. 27
Republic Exploration Co. 51
Rogers Geophysical Co. 47
Ruska Instrument Corp. 74

SEG 4, 8, 26
Schlumberger Well Surv. Corp. 57
Seismic Engineering Co. 28
Seismic Explorations, Inc. 53
Seismograph Service Corp. ..... Cover III
Sharpe Instruments Ltd. 38
Southern Geophysical Co. 48
Southwestern Industrial Electronics Co. 77
Insert between pages 64-65
Spang & Company 10
Stardrill Keystone Corp. 40
States Exploration Co. 76
Surveyors Service Co. 4

Tex-Tube, Inc. 58
Texas Seismograph Co. 24
Tidelands Exploration Co. 33
Triad Transformer Corp. 44

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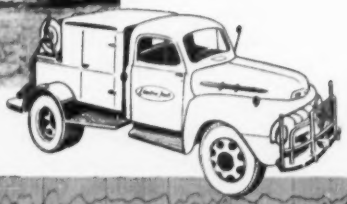

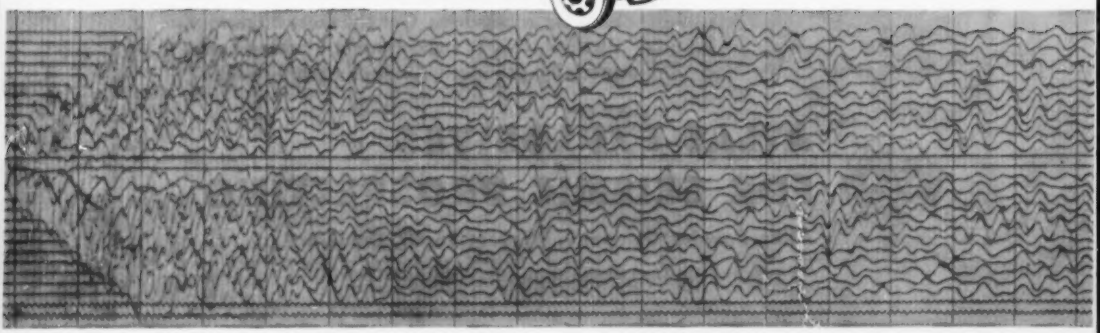

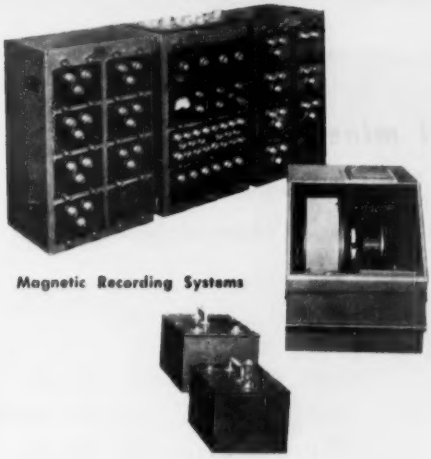

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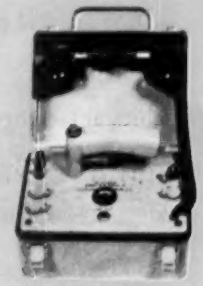

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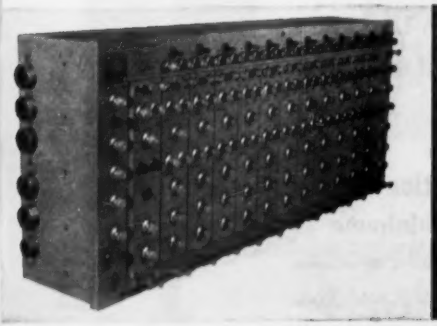

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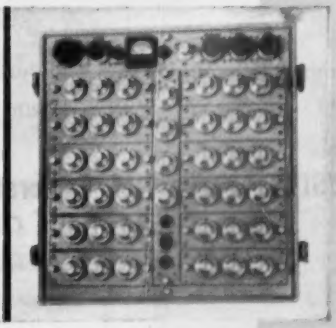

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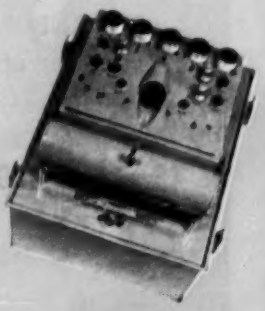

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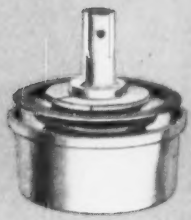

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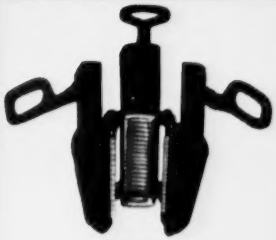

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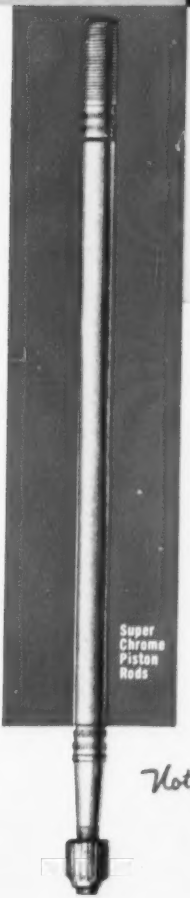

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VOLUME XXII JANUARY, 1957 NUMBER 1

GEOPHYSICS

PHYSICS AND GEOPHYSICS

Geophysics is a part of physics. Specifically it is the *Physics of the Earth*. It represents the effort of physicists to solve the problems associated with the earth. Exploration geophysics relates to that particular part of geophysics concerned with the search for petroleum and other mineral resources. In the search for these mineral resources it is important that the exploration geophysicist maintain a close cooperation with the geologist, for these two disciplines of physics and geology bring to bear upon the problem two entirely different philosophies, each of which makes its separate contribution to the successful solution of the problem of delineating geologic structures and discovering buried mineral deposits.

The development of the various methods and instruments of geophysical prospecting has been carried out through the efforts of physicists over a period of approximately thirty-five years with the result that the geophysical prospecting art has, within recent years, mushroomed in an amazing degree to the great benefit of the petroleum industry.

Just as close collaboration between the geophysicist and the geologist is essential for the discovering of today's oil today, so must exploration geophysics maintain and strengthen its contact with the basic and broader domains of physics if we are to forge sharper and more powerful tools in the search for tomorrow's oil.

It was in the interest of strengthening these bonds to the basic and broader domains of physics that the Society of Exploration Geophysicists invited Dr. Paul E. Klopsteg, associate director of the National Science Foundation and past chairman of the governing board of the American Institute of Physics, to be a guest speaker at its 26th annual meeting of the Society held in New Orleans, Louisiana, October 29–November 1, 1956. In the following paper Dr. Klopsteg has brought to the readers of GEOPHYSICS at an opportune time a discussion of *Physics in America and the American Institute of Physics*. It is to be hoped that this paper by Dr. Klopsteg will be the beginning of a continuing effort to strengthen our ties with other physicists, so necessary for the flow of men and ideas from basic physics into the geophysical prospecting art. Geophysical prospecting has much to offer the physicist in the way of challenging problems, especially in the field of the propagation of transient elastic disturbances in solid bodies. This particular field is basic to seismic prospecting, which is the most effective of the geophysical prospecting methods, and it is also hoped that this paper by Dr. Klopsteg will represent the beginning of a wider interest of physicists, from the broader fields of physics, in the Society of Exploration Geophysicists and its journal, GEOPHYSICS.

THE EDITOR

GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 2–5

PHYSICS IN AMERICA AND THE AMERICAN INSTITUTE OF PHYSICS*

PAUL E. KLOPSTEG†

The titles in your scientific program confirm the validity of the name of your society. You are physicists interested in the composition and content of the earth's outer shell. Yours is one of the key professions on which the material welfare of the human race increasingly depends, and without which it could not long continue in its present state of well-being. My own career, like that of most of you, derives from my interest in physics and its applications. With keen awareness of this community of interest, I am happy indeed, and honored as well, to speak to you about physics and the organization which has been serving it so effectively for more than a quarter century.

Physics has come a long way since the day, not too many years ago, when the American Physical Society was holding a meeting in a California city. It was an esoteric mystery to most of the lay public then. To the man on the street physics was something the doctor prescribed for what ailed him. Newspaper reporters covering the sessions, as well as the editors in the home offices, were hard put to describe the sessions in understandable prose. Finally, in desperation, the biggest of the local papers blossomed forth with the headline: BODY BUILDERS MEET HERE.

We hope and believe that great progress has been made in giving the public some understanding of what a physicist does, and what he does not do. Let us consider for a moment what physics in this country was like a little over a half century ago, in 1899, when the American Physical Society was founded.

Until World War I physicists could be numbered only in the hundreds. Many if not all of them held teaching posts in universities. Roentgen had discovered X-rays in 1896. Maxwell had, somewhat earlier, postulated electromagnetic waves and the electromagnetic theory of light, Hertz had discovered the waves and Marconi had begun to put them to use. Becquerel had found evidence of invisible radiation which led to the discovery of radium by the Curies. J. J. Thomson and his students were identifying the electron and its properties. Radiation and field theory were being developed. A young man named Albert Einstein was applying his genius to profound theories of relativity. A ferment of discovery was in the air, largely as a result of work by physicists in England, Germany and other European countries. By 1956 standards, the pace was perhaps leisurely. At any rate, the society meetings were. American physics, like American

* Invited paper presented before the 26th Annual Meeting of the Society on October 29, 1956 in New Orleans, Louisiana.

† Associate director of the National Science Foundation and past chairman of the American Institute of Physics.

biology and medicine, drew much of its sustenance and strength from Europe.

With World War I came a significant change. Government leaders saw that physics had much to offer besides a broad scientific and cultural background. Physics had immediate pragmatic, military value on land, on the sea and in the air, corresponding to the three states of matter with which it deals. In ordnance and communications physicists made substantial contributions in World War I. Here it is possible for me to speak from personal experience, since fortuitous circumstances in 1917 brought me to Sandy Hook Proving Ground as one of the first physicists in ordnance research and development. Locating guns by sound-ranging methods was a forerunner of your more sophisticated methods of locating oil deposits. Incidentally, I was carried on the rolls not as a physicist, but as "engineer at large."

After that war, there was acceleration in growth, but not because of government recognition of its value to the military. Many of you may remember the niggardliness with which the Congress made its appropriations for the national defense, with virtually nothing for research and development. It was not until war clouds loomed on the European horizon in the late thirties that realization slowly dawned that we had better be doing something along scientific and technological lines. In the meantime, many industrial concerns had realized the value of research and development, and were employing physicists. Among your senior members are physicists who became interested in applying the science of their specialization to the discovery of petroleum deposits. Out of these beginnings a great industry has developed. I don't know whether their companies in the early days had the same inhibition that still obtains in some firms about calling them physicists. Even today there are large employers who list them not as physicists, but as engineers.

In recent years, following World War II, physics has been expanding almost explosively. The physicist is the most wanted man in America—by industry. Most ivory-hunters for industry now come right out into the open, and tell the world that they are looking for physicists. I don't have to labor the point before this audience, but I would like to give you some idea of the amazing growth of physics.

The American Physical Society is the oldest of the member societies of the American Institute of Physics. During its first year of existence its membership was 59; today it is about 12,000.

An index of growth of activity by physicists can be found in the number taking both undergraduate and postgraduate work in our colleges and universities. Immediately after World War II there was a sharp slump in this number. The trend has been reversed, is now strongly on the upgrade, and under the stimulation of the great demand for physicists, and of activities through organized effort to increase the number of physicists, it will undoubtedly continue upward.

Following World War II there occurred an exodus of able physicists from academic posts into government and industrial positions. Within the extent that

this continues, the appeal of government seems less potent than that of industry. The strength of the appeal is probably directly related to the size of the salary. The new fields in this old science which have opened up in recent years are—as I need hardly remind you—nuclear physics including health physics and a diversity of scientific applications of fission products and reactor techniques; chemical and solid state physics in which crystalline solids, semiconductors and metals are important targets of investigation; electron physics, underlying the great and expanding electronics industry; biophysics; and, as the solid and indispensable foundation for all of these, mathematical physics.

It has been said that World War I caused the chemical industry to become one of our industrial giants. If war was indeed responsible, we may with equal assurance say that World War II did the same for the industries that are based on physics. Certainly the second World War, with the tremendous developments that it necessitated, gave physicists in all categories an opportunity of demonstrating what they could do. The record of technological achievement is one of which they, along with their fellow-scientists in other fields, may rightly be proud.

Physics as we see it today is still not too well understood by the average, non-scientist citizen. Of course, he knows that it is a science of great importance to our defense, and perhaps he also knows that much of the national economy rests upon it. But many have the image of the physicist as being a longhair, spending his time making bigger and more destructive weapons, and altogether somewhat irresponsible. Certainly he created the atom bomb and the hydrogen bomb, didn't he? An important function of the AIP is to place before the public a factual picture of what physics is, and what the physicist does, and to emphasize that it isn't the physicist who determines whether or how the weapons of destruction are used.

The typical physicist of today, with a median age in his middle or late thirties, can look upon a record of solid accomplishment, both in basic research and in the applications of fundamental knowledge, and of the tremendous impact of his accomplishment on technological progress in America. He may take pride in the part he has played in providing the knowledge and to some extent the skill which made radar, modern radio, television and other methods of communication possible. Include also the peacetime developments of atomic energy, and all that this implies; and such important items as modern lighting, and modern means of transportation. I do not imply or suggest that physicists were solely responsible for these things; but their part in making them possible has been most significant. Nor could I be easily forgiven for being presumptuous if I were to try to tell a group of geophysicists how physics and the earth sciences together constitute the foundations of their profession. From the accomplishments recited, and from the accomplishments in your field, which you know so much better than I, we get an appreciation of how important it is that physics, whatever its specialized

label, speak with a single voice on matters in which it is involved. An example is an attack on shortages in professional manpower.

The need for a central agency for all physicists became increasingly apparent to many members of the profession prior to the founding of the American Institute of Physics in 1931.

The Institute had its inception in the increasing specialization and the complexity of scientific research. It was becoming clear in 1929 that, just as electrical engineering, for example, became an independent profession when this branch of the science became "practical," so would those physicists interested in optics and acoustics, with their independent organizations, also break away from the central stem, unless a way were found of keeping them united. The Optical Society of America was founded in Rochester in 1916, became a vigorous organization, and drew into its meetings—at first held simultaneously and in the same location as the Physical Society meetings—those physicists interested in optics. Parenthetically I may mention that three years later, the *Journal of the Optical Society* was begun. After a brief hiatus, it was reestablished with the cooperation of the Scientific Instrument Makers of America, as the *Journal of the Optical Society and Review of Scientific Instruments*. With the Optical Society a member of the Institute of Physics, arrangements were made in 1937, for the Institute to take over the *Review of Scientific Instruments*, which it has since published as an independent journal.

Similarly, the Acoustical Society had been organized in 1929, in part as the result of great interest and activity in architectural acoustics. It provided the instrumentality through which the community of interests of the research physicists and the acoustical engineers could be fostered. The society, as a member of the Institute, has grown with the manifold developments in acoustics, such as measurements of sound and noise, ultrasonics, sonic devices for undersea warfare, and audio communications. Acoustics is a branch of knowledge which cuts across science, the arts and the humanities, and thus attracts the interest of psychologists, physiologists, architects, musicians and engineers in addition to that of physicists.

The Physical, Optical and Acoustical Societies formed a joint committee and invited the Society of Rheology to have representation at a meeting in Washington on May 3, 1931, the founding date of the AIP. The American Association of Physics Teachers, which had also become established as an independent society in 1930, upon invitation became one of the founder societies of AIP. Dr. Henry A. Barton, who has served as Institute director since its beginning, was recruited from the physics faculty at Cornell University. Money was supplied and financing greatly aided, during the first years, by the Chemical Foundation.

By definition and under its constitution the Institute is an independent, nonprofit organization comprising member societies and individual members. Among its important functions are to aid the publication of the results of research, to

maintain a sense of unity among physicists in all categories, and to work towards improvement in public understanding of the place of the physicist in society, and of the meaning of his work to society.

In its articles of incorporation, at the time the Institute became a non-profit membership corporation under the laws of the State of New York in 1932, the following objectives are recited:

"The advancement and diffusion of knowledge of the science of physics and its applications to human welfare"; and it is stated that "to this end it is part of the purpose of this corporation to undertake, among other measures, the publication of scientific journals devoted wholly or mainly to physics and related sciences; to serve the public by making available to journals, newspapers, and other channels of public information reliable communications as to physics and its progress; to cooperate with local, national and international organizations devoted to physics; to promote unity and effectiveness of effort among all those who are devoting themselves to physics by research, by application of its principles, by teaching or by study; and to foster the relations of the science of physics to other sciences and to the arts and industries."

You will note that this charter provides a broad base for the operations of the Institute in the service of its member societies, which are completely autonomous both in management and finances. It indicates also that the Institute is not merely a centralized publishing agency for them, but that it is an instrument for achieving common goals by combining the strengths of existing organizations in the field of physics. In carrying out its publications function for the member societies, it publishes *The Physical Review*, *Reviews of Modern Physics*, and *Bulletin of the American Physical Society; Journal of the Optical Society of America; Journal of the Acoustical Society of America*, and *Noise Control;* and the *American Journal of Physics*. I have previously mentioned the *Review of Scientific Instruments* as an Institute journal. In addition, the Institute on its own account publishes the *Journal of Chemical Physics*, and the *Journal of Applied Physics*. All of these are journals of record, or archives journals. In the fulfillment of its function of promoting unity and effectiveness of effort among its members, and of creating among them a sense of belonging together, the Institute since May, 1948, has been publishing its "member house organ," *Physics Today*, which goes to all individual members, to the number of about 18,000, with some additional circulation to non-member subscribers. It is not an archives journal, and it is written with a minimum of specialized professional jargon, so that its articles in the main fall within the comprehension of any intelligent reader.

In addition to the corporate society members and the individual members, the Institute has associated with it a number of local organizations and other smaller groups as affiliates. It also has 93 industrial associates interested in physics, which pay the Institute $250 each per year. This money, together with prorated contributions from the member societies, and advertising revenue, are

used in supporting the journals and other activities of the Institute. The advertising revenue from *Physics Today* is, as of this year, sufficient to pay for its publication and distribution free to the membership.

A special word should be said about the relations between industry and the Institute. Industry's interest is tangibly expressed in the Institute's 93 industrial associates. The Institute's interest in industrial physics led to the appointment in 1934 of an advisory council on applied physics, which, in connection with a symposium on Physics in Industry, recommended a more open attitude by industry as well as government towards the employment of physicists, and which also led to the publication of the *Journal of Applied Physics*. Special symposiums in applied physics were held on such subjects as temperature measurement, metals, textiles and automobiles.

The growth of physics, and with it, the activities of the Institute, may perhaps best be indicated by the increasing rate of publication in the field. From 1943 to 1955 the number of pages published during the year had quadrupled, 4600 to 18000. At the earlier date, the Institute was in need of larger quarters, after having spent 12 years in rented space. It was able to buy the present headquarters on East 55th Street, New York. Because of my membership on the Board at that time, I recall clearly the assumption made, as the property was acquired, that it would adequately serve as headquarters for 25 years. We weren't very astute or foresighted, for in less than half that time the building was outgrown. A significant fact was that its purchase was made possible by the contributions of individual physicists to the extent of $70,000, the price then paid. The Institute has now sold the building, and has purchased another, with nearly three times the space, on East 45th Street. This requires conversion from loft to office space. For this undertaking, together with the task of coping with its still-mounting problem of publication and some lesser activities, the Institute has undertaken to raise half a million dollars for a development fund. Most of this will be sought from those industries in which physics is important.

With 25 years of operating experience, the Institute has developed an effective pattern of service activities in addition to its major job of publication and publications management. It assists member societies in holding meetings and in managing their business affairs. It provides direct aid at the meetings—and physicists hold many, many meetings—although the member societies control their own arrangements, topics and speakers. The Institute sends out bills for most of the member societies, collects the dues and makes remittances to the treasurers. It sends out notices and performs at reasonable cost those vital clerical services that keep societies running smoothly. It provides assistance in accounting and legal matters. In the past 12 years it has spent $200,000 of its own funds for new publications, and for the improvement of its operating facilities.

It cooperates with government and private agencies in matters of common interest. For the National Science Foundation it has taken the responsibility of

translating and publishing Russian physics journals, and works with that agency in the development and maintenance of its national register of scientific personnel. It cooperates with other private organizations in such matters as the recruitment and training of scientific manpower and its effective employment.

One of its most significant activities is its free placement service to all firms that employ physicists, to educational institutions and to government agencies. The service operates continuously to maintain a register, distribute information and arrange interviews. It brings its files and personnel to some of the larger meetings of the societies, and, for the interviews it arranges, it provides suitable space in which the prospective employer and job candidate may conduct their conversation. The shortage of physicists makes the service particularly important to employers. An index of the shortage is the number of registrants this year—about 300, of whom only 8 were not currently employed—as compared with the number of reported openings—about 2,000—only one registrant for more than six jobs!

Another of the Institute's programs is that of informing the public about physics and its value to society. It endeavors to depict physics rationally and objectively, to show what kind of person the physicist is and what he does, and to encourage young people to choose physics as their profession. It emphasizes not merely the pragmatic value of the science, but tries to show that knowledge of the physical world is an important part of a liberal education. Through its Section on Public Relations and Information it operates to interpret research to the public through the press accurately and in a manner to interest the general reader. This section answers inquiries from students and prospective students, and supplies copies of the booklet, *Physics as a Career*, to schools and colleges.

The Institute has warmly welcomed the interest in its affairs of the Society of Exploration Geophysicists, and very much appreciates the opportunity offered on this program of telling you its story. From my remarks I hope you have received a clear picture of what I have tried to convey, namely what the Institute is, what its activities are, and the place it fills with respect to societies having to do with basic and applied research in physics, and with respect to industry, government and the general public. I have refrained from dwelling upon the financial and organizational problems and troubles of the early years. The only point in mentioning them now is to recognize that they existed, that they have been overcome, and that today we have a flourishing organization whose value to the member societies and the individual members can be very great, and that this value will be what they choose to make it.

It has been a delightful experience to meet with you and appear before you, and I express my personal thanks for the opportunity.

GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 9-22, 2 FIGS.

THE USE OF A LEAST SQUARES METHOD FOR THE INTERPRETATION OF DATA FROM SEISMIC SURVEYS*

A. E. SCHEIDEGGER† AND P. L. WILLMORE†

ABSTRACT

During large-scale seismic surveys it is often impossible to arrange shot points and seismometers in a simple pattern, so that the data cannot be treated as simply as those of small-scale prospecting arrays. It is shown that the problem of reducing seismic observations from m shot points and n seismometers (where there is no simple pattern of arranging these) is equivalent to solving $(m+n)$ normal equations with $(m+n)$ unknowns. These normal equations are linear, the matrix of their coefficients is symmetric. The problem of inverting that matrix is solved here by the calculus of "Cracovians," mathematical entities similar to matrices. When all the shots have been observed at all the seismometers, the solution can even be given generally. Otherwise, a certain amount of computation is necessary. An example is given.

1. *The Seismic Equations*

The equation giving the travel-time of a seismic wave through a structure consisting of two materials separated by a plane interface may be written in the form

$$v_1 t = (H_a + H_b) \cos\theta + \Delta \sin\theta \cos\phi \qquad (1.1)$$

where H_a and H_b are the lengths of the perpendiculars drawn from the source A and the detector B to the interface, v_1 and v_2 are the velocities in the upper and lower layers respectively, $\sin\phi = v_1/v_2$, $AB = \Delta$ and ϕ is the angle between AB and the interface (Fig. 1).

Numerous special forms of equation (1.1) are used in refraction prospecting. For example, if an explosion is fired on the extension of a straight line of geophones, we may put $H_b = H_a - \Delta \sin\phi$, and the equation takes on the form

$$t = \frac{2H_a \cos\theta}{v_1} + \frac{\Delta}{v_2}(\cos\phi - \sin\phi \cot\theta) \qquad (1.2)$$

which is used for determining v_2 and ϕ separately. An alternative approach is that of arc shooting, in which the geophones are arranged in a circle around the shot. In that case H_a and Δ are constant for each shot, and the value of t determined from the record of each geophone yields the corresponding value of H_b directly.

In earthquake studies and large-scale explosion work, the distribution of sources and the available sites for recording equipment are unlikely to fit into a simple pattern, so that one needs a method of treating the set of equations of

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† Dominion Observatory, Ottawa, Ontario, Canada.

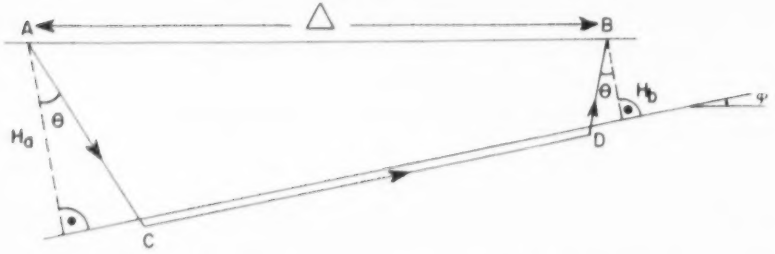

FIG. 1. Propagation of a seismic wave in a two-layer medium.

type (1.1) which will arise from a general distribution of sources and seismometers. In searching for such a method, we note first that the equations will take on a much simpler form if we can assume that $\cos\phi = 1$, so we consider the error in $H_a + H_b$ which would arise from this assumption. To do this, we put

$$\cos\phi = 1 - \frac{\phi^2}{2} + o(\phi^4)$$

and rewrite (1.1) in the form

$$H_a + H_b = v_1 t \sec\theta - \Delta \tan\theta\left(1 - \frac{\phi^2}{2} + o(\phi^4)\right).$$

From Fig. 1 it is seen that

$$H_a - H_b = \Delta \sin\phi.$$

Putting

$$\phi = \frac{H_a - H_b}{\Delta} + o(\phi^3)$$

we have

$$H_a + H_b = v_1 t \sec\theta - \Delta \tan\theta + \frac{\phi}{2}(H_a - H_b)\tan\theta + o(\phi^3)$$

Hence if $\tan\theta$ is less than 2, the error introduced in $(H_a + H_b)$ by setting $\phi = 0$ will not exceed $(H_a - H_b)\phi + o(\phi^3)$. This means that steeply dipping parts of the structure may appear to be distorted as a result of the simplifying assumption, but that such distortions are not likely to be bad enough to conceal the main outlines of the feature.

Further errors may arise when the interface between the two materials is not plane. Firstly, the value of ϕ will generally be different at the two ends of the line, so that an error proportional to the difference between the two values of

$\cos\phi$ may be introduced into the estimate of H. This will generally be negligible. Larger errors may arise if the segment CD of the wave path is interrupted by irregularities of the interface, but this difficulty would be equally severe if any other form of the refraction equation were used.

There is therefore a wide range of conditions under which we can set $\cos\phi = 1$ in (1.1), giving

$$t = a + b + \Delta/v_2 \tag{1.3}$$

In this equation, a and b are "time terms" of the form $H\cos\theta/v_1$. Each time term is characteristic of H and v_1 at a given point on the ground, and will enter into the travel-time along all the wave paths which begin or end at that point.

If m recording stations observe waves from n sources, up to nm equations of type (1.3) may be obtained. The problem is then to determine the best values of the velocity v_2 and the time terms for all sources and stations. Finally, the time terms can be interpreted in terms of the corresponding depths H, so that the contours of the interface can be obtained.

2. *Derivation of the Normal Equations*

The observational equations (1.3) can be put in the form or,

$$a_i + b_j = t_{ij} - \Delta_{ij}/v \tag{2.1}$$

or, in general terms

$$p_{si}x_i = m_s \tag{2.2}$$

where x_i stands for all the time terms a and b, and m_s represents the right hand side of (2.1) for a particular observation of travel-time at a particular distance. The coefficients p_{si} will be unity when the value of i refers to the shot point or seismometer for which the travel-time appears in the sth equation, and will otherwise be zero.

Apart from v, the problem contains $(n+m)$ unknowns. These unknowns cannot all be determined uniquely, for if an arbitrary constant α is subtracted from all the shot time terms a_i and added to the station terms b_j, the observational equations are unaltered. The value of one time term can therefore be assumed arbitrarily, and is set equal to zero to simplify the calculations. After the calculations have been completed, the arbitrary term is introduced. Its possible values are limited by the fact that none of the final time terms can be significantly negative, as this would imply a negative depth for the assumed lower layer. Any increase in the value of α within these extreme limits will produce an apparent elevation of the marker layer under all the shot points and an equal depression under all the detectors. The final value of α may be chosen either to minimize the resulting apparent discontinuities of the structure, or to concentrate them in the vicinity of known geological faults.

The observational equations (2.2) are reduced to a set of $(n+m-1)$ normal equations in the ordinary way (i.e. the normal equation s is produced by multiplying each of the k observational equations by the coefficient p_{st}, and adding). The normal equations are written

$$q_{st}x_t = l_s \tag{2.3}$$

The solution of equations of the type of (2.3) is tedious at best. There exist a great variety of methods (see Forsythe, 1953), to achieve this, and we have chosen the Cracovian method of Banachiewicz (1938, 1949a, b) for a demonstration of how the problem can be brought within the range of a desk calculator. The Cracovian method is equivalent to a method using matrices, but the actual mechanics of writing out the terms during the computations is greatly facilitated through the use of Cracovians. For large surveys, however, the employment of high speed computing equipment is indicated in which case methods of solution different from that considered here may be preferable.

3. *The Cracovian Method*

Cracovians are arrays of numbers similar to Caleyan matrices, but differing from them in the method of multiplication. Thus consider two Cracovians $\boldsymbol{a}$ and $\boldsymbol{b}$, viz:—

$$\boldsymbol{a} = \begin{pmatrix} a_{11} & a_{21} \cdots a_{n1} \\ a_{12} & a_{22} \cdots a_{n2} \\ \cdots & \cdots \cdots \end{pmatrix} = \|a_{ij}\| \tag{3.1}$$

$$\boldsymbol{b} = \begin{pmatrix} b_{11} & b_{21} \cdots b_{n1} \\ b_{12} & b_{22} \cdots b_{n2} \\ \cdots & \cdots \cdots \end{pmatrix} = \|b_{ij}\| \tag{3.2}$$

The product $\boldsymbol{c} = \boldsymbol{a} \cdot \boldsymbol{b}$ is defined as follows, using the summation convention:

$$c_{ik} = a_{ij}b_{kj} \tag{3.3}$$

The summation convention is that when an index appears twice on the same side of the equation, it is given all possible values and the results added together. Since the first index always refers to the column and the second one to the row, equation (3.3) represents the sum of the products of the pairs of coefficients which occur in each row of the ith and kth columns. The psychological ease of the method derives from the fact that the summation includes only the terms of two columns, not rows and columns as in matrices.

The set of normal equations (2.3) are now seen to involve the two particular sets of terms which can be represented in Cracovian notation as follows:

$$\boldsymbol{q} = \boldsymbol{p} \cdot \boldsymbol{p} \tag{3.4}$$

$$\boldsymbol{l} = \boldsymbol{m} \cdot \boldsymbol{p} \tag{3.5}$$

The Cracovian $\boldsymbol{q}$ is square and symmetric; thus the normal equations can be written as follows:—

$$\boldsymbol{x} \cdot \boldsymbol{q} = \boldsymbol{I} \tag{3.6}$$

The solution of this system yields the least square solution for the array of unknowns represented by $\boldsymbol{x}$. The solution is

$$T\boldsymbol{x} = \boldsymbol{q}^{-1}\boldsymbol{I} \tag{3.7}$$

where $\boldsymbol{q}^{-1}$ is that Cracovian which, multiplied into $\boldsymbol{q}$, yields the unit Cracovian

$$\boldsymbol{q}^{-1}\boldsymbol{q} = \boldsymbol{I} = \begin{pmatrix} 1 & 0 & 0 \cdots \\ 0 & 1 & 0 \cdots \\ \cdots & \cdots & \cdots \end{pmatrix} \tag{3.8}$$

and $T\boldsymbol{x}$ denotes the Cracovian $\boldsymbol{x}$ with all its terms transposed across the main diagonal.

The problem is thus reduced to finding the inverse $\boldsymbol{q}^{-1} = \boldsymbol{Q}$ of $\boldsymbol{q}$. Banachiewicz (1938) shows that every symmetric Cracovian can be represented by the product of two identical triangular Cracovians, i.e. Cracovians where there are zeros below the main diagonal. Thus writing

$$\begin{pmatrix} q_{11} & q_{21} \cdots \\ q_{21} & q_{22} \cdots \\ \cdots & \cdots \end{pmatrix} = \begin{pmatrix} g_{11} & g_{21} \cdots \\ 0 & g_{22} \cdots \\ \cdots & \cdots \end{pmatrix} \cdot \begin{pmatrix} g_{11} & g_{21} \cdots \\ 0 & g_{22} \cdots \\ \cdots & \cdots \end{pmatrix} \tag{3.9}$$

we find

$$\begin{aligned} q_{11} &= g_{11}^2 \\ q_{12} &= q_{21} = g_{21}g_{11} \\ q_{22} &= g_{21}^2 + g_{22}^2 \\ &\cdots\cdots\cdots \end{aligned}$$

so that the elements of $\boldsymbol{g}$ can be calculated one by one. The most involved operation that has to be performed is the drawing of a square root, the rest are cumulative multiplications. As a running check of the computation, one can form the sum of the rows of $\boldsymbol{q}$ and treat it as an additional column of $\boldsymbol{q}$. This yields an additional column of $\boldsymbol{g}$ which must be the sum of the rows of $\boldsymbol{g}$.

Finally, the Cracovian $\boldsymbol{Q} = \boldsymbol{q}^{-1}$ is found from the equation

$$\boldsymbol{g}^{-1} = \boldsymbol{q}^{-1}(T\boldsymbol{g}) \tag{3.10}$$

The last equation is an outcome of the Algebra of Cracovians (see Banachiewicz, 1938). For the evaluation of $\boldsymbol{q}^{-1}$ according to Eq. (3.10), only the diagonal elements of $\boldsymbol{g}^{-1}$ are needed. These are simply

$$(g^{-1})_{ii} = \frac{1}{g_{ii}} . \tag{3.11}$$

From Eq. (3.10), the terms of q^{-1} can be found one by one, starting from the bottom right hand corner of the array of numbers and making use of the fact that the Cracovian q^{-1} must be symmetric, because q is.

Using the relationship $I = mp$ (Equation 3.5) and recalling that the components of p are zero or unity, we find that the terms of I are given by

$$I_i = \sum_k t_{ik} - \frac{1}{v} \sum_k \Delta_{ik} \tag{3.12}$$

where the index k takes the values appropriate to all stations which have observed the shot i (or to all shots which have been observed at station i). The time terms x are obtained by multiplying the Cracovian Q into I in accordance with (3.7). It will be noted that most of the labor of the solution is devoted to manipulating the scheme of coefficients to form Q, whereas the observational data only appear in the formation of I. It follows that the observations can be checked and corrected at a late stage in the computations, but that no additions or rejections can be made without destroying Q.

On inserting the time terms x into the observational equations (2.1), we obtain a set of expressions of the form

$$c_{ik} - \frac{1}{v} d_{ik} = \delta_{ik} \tag{3.13}$$

where δ_{ik} is the residual. The sum of the squares of the residuals may be minimized in the ordinary way by setting

$$v = \frac{\sum d^2_{ik}}{\sum c_{ik} d_{ik}} . \tag{3.14}$$

A further result of the theory of Cracovians is that the terms in the main diagonal of $Q = q^{-1}$ are the inverse weights of the unknowns—if all observations have the same weight. The square of the standard deviation e of x_i is then given by

$$e_i^2 = Q_{ii} \delta^2 / (K - L) \tag{3.15}$$

Where δ^2 is the sum of the squares of the residuals from the observational equations, K is the number of observational equations, and L is the number of unknowns.

4. *Special Solution for Complete Sets*

The problem is greatly simplified if all the n shots have been observed at all the m stations. In this case, the Cracovian p^2, i.e. the scheme of coefficients of the normal equations has the following special form:

$$\boldsymbol{p}^2 = \begin{pmatrix} m\boldsymbol{I}' & \boldsymbol{E}' \\ \boldsymbol{E}'' & n\boldsymbol{I}'' \end{pmatrix} \tag{4.1}$$

Here the $\boldsymbol{E}$'s are Cracovians having "one" in all positions, the $\boldsymbol{I}$'s are identity Cracovians. The Cracovian $\boldsymbol{I}'$ is square and has n columns, the Cracovian $\boldsymbol{I}''$ has $(m-1)$ columns (since the b for the last station has been put equal to zero and hence does not require an equation). The Cracovian E' has $(m-1)$ columns and n rows, E'' is its transpose. In this case the inverse $\boldsymbol{Q}$ of $\boldsymbol{p}^2$ has the following form:

$$Q = \begin{pmatrix} \begin{pmatrix} x & y & y \cdots \\ y & x & y \cdots \\ y & y & x \cdots \\ \cdots & \cdots & \cdots \end{pmatrix} & z\boldsymbol{E}' \\ z\boldsymbol{E}'' & \begin{pmatrix} \xi & \eta & \eta \cdots \\ \eta & \xi & \eta \cdots \\ \eta & \eta & \xi \cdots \\ \cdots & \cdots & \cdots \end{pmatrix} \end{pmatrix} \tag{4.2}$$

The condition that $\boldsymbol{Q}\boldsymbol{p}^2 = \boldsymbol{I}$ yields immediately the following conditions for x, y, z, ξ, η:

$$xm + z(m-1) = 1 \tag{4.3}$$

$$ym + z(m-1) = 0 \tag{4.4}$$

$$x + y(n-1) + zn = 0 \tag{4.5}$$

$$nz + \xi n = 1 \tag{4.6}$$

$$nz + \eta n = 0 \tag{4.7}$$

This is a system of 5 linear equations for five unknowns, whose solution is

$$x = \frac{n+m-1}{nm} \tag{4.8}$$

$$y = \frac{m-1}{nm} \tag{4.9}$$

$$z = -\frac{1}{n} \tag{4.10}$$

$$\xi = \frac{2}{n} \tag{4.11}$$

$$\eta = \frac{1}{n} \tag{4.12}$$

5. *Example*

The procedure described in the last sections can be most easily visualized on a hypothetical example. Let it be assumed that one has a structure that is horizontal to the SW of a line striking at N 45° W, and dipping at some angle θ to the NE of that line (see Fig. 2). This structure is to be investigated by a series of interconnected shootings, where the charges are exploded at the points desig-

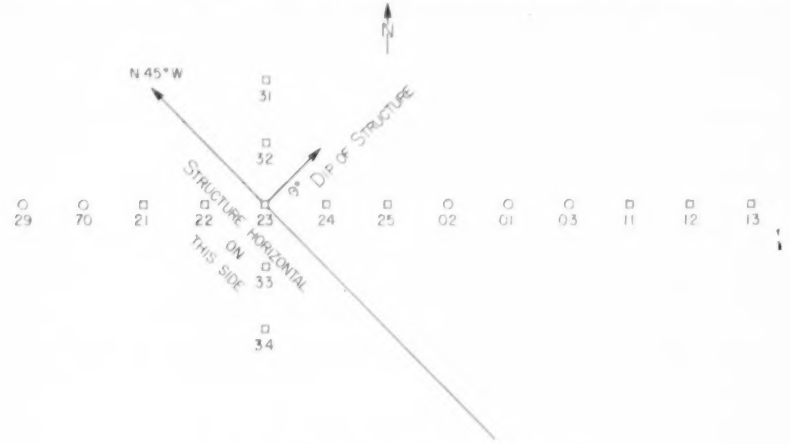

FIG. 2. Assumed layout of shot points (squares) and detectors (circles) on an idealized geological formation.

nated by the squares 11, 12, 13, 21, 22, 23, 24, 25, 31, 32, 33, 34 in Fig. 2, and the seismic stations are at the points designated by the circles 01, 02, 03, 29, and 70. It is assumed that travel-times were observed between the shot points and stations for which distances are given in Table I. The structure as envisaged in Figure 2 implies that the time terms to the SW of the dividing line should be constant, say 0.5 sec.; to the NW they increase with the distance from the line, and the rate of 1 second per 100 km. has been assumed. This produces the time terms listed in the last column of Table VIII. Assuming a "basement velocity" of 6.0 km./sec., the hypothetical travel-times of Table II are obtained whereby the rounding off to 1 km. in distances and 1/10 second in times introduces a small random error.

It will now be shown how the time terms can be calculated from the travel-times of Tables I and II. According to the above, it is assumed that there are a total of 27 usable readings; 17 time terms and the "basement velocity" are to be determined. The problem is to be treated as a single least square solution.

First of all, one observes that the time terms a_{31}, a_{32}, a_{33}, a_{34} and b_{29} have been observed in one instance only. The corresponding residuals can therefore always

TABLE I

DISTANCE IN KILOMETERS

	01	02	02	29	70
11	40	60			
12	60	80			
13	80	100	60		
21	120		140	40	20
22	100		120		40
23	80		100		60
24	60		80		80
25	40		60		100
31	90				
32	82				
33	82				
34	90				

be made zero, by calculating the terms after the completion of the least squares solution. The least square solution has, therefore, to include only the terms a_{11}, a_{12}, a_{13}, a_{21}, a_{22}, a_{23}, a_{24}, a_{25}, b_{01}, b_{02}, b_{03}, and b_{70}. Of these, b_{70} is set equal to zero for the purposes of the calculation. The arbitrary term α will be added later.

The scheme $\boldsymbol{p}$ of coefficients of the observational equations is therefore outlined as shown in Table III. The Cracovian $\boldsymbol{q} = \boldsymbol{p}^2$ is shown in Table IV. This Cracovian is the product of two triangular Cracovians $\boldsymbol{g}$ which have been calculated step by step following the procedure in Sec. 3. The result is shown in Table V. Next, the relevant terms of the inverse of $\boldsymbol{g}$ have been calculated; they are shown in Table VI. Finally, the inverse $\boldsymbol{Q}$ of $\boldsymbol{q}$ has been calculated; it is shown in Table VII. It may be noted that, if all the shots had been observed at all the stations, the corresponding Cracovian $\boldsymbol{Q}$ could have been written down immediately by means of formulas (4.2–4.12), thus saving the labor of calculating $\boldsymbol{Q}$ longhand as was done here. There is therefore an inducement to expend as much effort as feasible during a field operation to obtain all possible readings; this saves subsequent calculating time.

TABLE II

TRAVEL-TIMES IN SECONDS

	01	02	03	29	70
11	9.1	12.3			
12	12.6	15.7			
13	16.0	19.2	12.8		
21	22.4		25.9	8.5	5.2
22	18.2		21.7		7.7
23	14.9		18.4		11.0
24	11.7		15.2		14.5
25	8.5		12.0		17.9
31	16.8				
32	15.4				
33	15.2				
34	16.6				

TABLE III

THE COEFFICIENTS OF THE OBSERVATIONAL EQUATIONS

a_{11}	a_{12}	a_{13}	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	b_{01}	b_{02}	b_{03}	$b_{70}(=0)$	Observations
1								1				9.1 − 40/v
1									1			12.3 − 60/v
	1							1				12.6 − 60/v
	1								1			15.7 − 80/v
		1						1				16.0 − 80/v
		1							1			19.2 − 100/v
		1								1		12.8 − 60/v
			1					1				22.4 − 120/v
			1							1		25.9 − 140/v
			1								(1)	5.2 − 20/v
				1				1				18.2 − 100/v
				1						1		21.7 − 120/v
				1							(1)	7.7 − 40/v
					1			1				14.0 − 80/v
					1					1		18.4 − 100/v
					1						(1)	11.0 − 60/v
						1		1				11.7 − 60/v
						1				1		15.2 − 80/v
						1					(1)	14.5 − 80/v
							1	1				8.5 − 40/v
							1			1		12.0 − 60/v
							1				(1)	17.9 − 100/v

TABLE IV

THE SCHEME OF COEFFICIENTS OF THE NORMAL EQUATION

	a_{11}	a_{12}	a_{13}	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	b_{01}	b_{02}	b_{03}	
a_{11}	2	0	0	0	0	0	0	0	1	1	0	21.4 − 100/v
a_{12}	0	2	0	0	0	0	0	0	1	1	0	28.3 − 140/v
a_{13}	0	0	3	0	0	0	0	0	1	1	1	48.0 − 240/v
a_{21}	0	0	0	3	0	0	0	0	1	0	1	53.5 − 280/v
a_{22}	0	0	0	0	3	0	0	0	1	0	1	47.6 − 260/v
a_{23}	0	0	0	0	0	3	0	0	1	0	1	44.3 − 240/v
a_{24}	0	0	0	0	0	0	3	0	1	0	1	41.4 − 220/v
a_{25}	0	0	0	0	0	0	0	3	1	0	1	38.4 − 200/v
b_{01}	1	1	1	1	1	1	1	1	8	0	0	113.4 − 580/v
b_{02}	1	1	1	0	0	0	0	0	0	3	0	47.2 − 240/v
b_{03}	0	0	1	1	1	1	1	1	0	0	6	106.0 − 560/v

TABLE V

THE TRIANGULAR CRACOVIAN g

	a_{11}	a_{12}	a_{13}	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	b_{01}	b_{02}	b_{03}
a_{11}	1.4142	0	0	0	0	0	0	0	0.7071	0.7071	0
a_{12}	0	1.4142	0	0	0	0	0	0	0.7071	0.7071	0
a_{13}			1.7320	0	0	0	0	0	0.5774	0.5774	0.5774
a_{21}				1.7320	0	0	0	0	0.5774	0	0.5774
a_{22}					1.7320	0	0	0	0.5774	0	0.5774
a_{23}						1.7320	0	0	0.5774	0	0.5774
a_{24}							1.7320	0	0.5774	0	0.5774
a_{25}								1.7320	0.5774	0	0.5774
b_{01}									2.2361	−0.5963	−0.8944
b_{02}										1.1450	−0.7570
b_{03}											1.6208

TABLE VI

RELEVANT TERMS OF THE CRACOVIAN g^{-1}

	a_{11}	a_{12}	a_{13}	a_{21}	a_{22}	a_{23}	a_{31}	a_{32}	b_{01}	b_{02}	b_{03}
a_{11}	0.7071	0	0	0	0	0	0	0	0	0	0
a_{12}		0.7071	0	0	0	0	0	0	0	0	0
a_{13}			0.5774	0	0	0	0	0	0	0	0
a_{21}				0.5774	0	0	0	0	0	0	0
a_{22}					0.5774	0	0	0	0	0	0
a_{23}						0.5774	0	0	0	0	0
a_{31}							0.5774	0	0	0	0
a_{32}								0.5774	0	0	0
b_{01}									0.4472	0	0
b_{02}										0.8734	0
b_{03}											0.6170

Finally, the time terms can be calculated by forming the product $\boldsymbol{QI}$. The result is shown in the first column in Table VIII. These time terms still contain the "basement velocity" v which has now to be determined. Inserting the time terms as found in Table VIII, into the observational equations of Table III, yields the terms c and d (cf. eq. 3.13) shown in Table IX. The quantity $1/v$ is treated as an unknown, and determined by a standard least squares solution according to formula (3.14). The result is $v = 6.0$ km./sec., as assumed beforehand. With this value for v, the residuals turn out to be as shown in the last column of Table IX. Finally, the time terms can be calculated, using the value found above for v. The result is shown in Table VIII. In conclusion, the missing time terms a_{21}, a_{22}, a_{23}, a_{31} and b_{03} can be calculated from the corresponding observational equations.

A discussion of the errors can be obtained as follows. The standard errors of the time terms which have been obtained from the Cracovian can be obtained from Eq. (3.15); they are solely given by the inconsistency of the observational equations. One obtains the values shown in Table VIII. The time term b_{70}, which has been set (arbitrarily) equal to zero, has no error resulting from the inconsistency of the equations, because the condition $b_{70} = 0$ has been satisfied *exactly*. Finally, the errors of those time terms that are calculated from only one observation are the sum of the errors of the one observation, and of the errors of the Cracovian time term occurring in it.

TABLE VII

THE CRACOVIAN Q

	a_{11}	a_{12}	a_{13}	a_{21}	a_{22}	a_{23}	a_{31}	a_{32}	b_{01}	b_{02}	b_{03}
a_{11}	1.0017	0.5017	0.4130	0.2001	0.2001	0.2001	0.2001	0.2001	−0.3646	−0.6388	−0.2355
a_{12}	0.5017	1.0017	0.4130	0.2001	0.2001	0.2001	0.2001	0.2001	−0.3646	−0.6388	−0.2355
a_{13}	0.4130	0.4130	0.7034	0.2001	0.2001	0.2001	0.2001	0.2001	−0.3162	−0.5099	−0.2839
a_{21}	0.2001	0.2001	0.2001	0.4668	0.1334	0.1334	0.1334	0.1334	−0.2001	−0.2001	−0.2001
a_{22}	0.2001	0.2001	0.2001	0.1334	0.4668	0.1334	0.1334	0.1334	−0.2001	−0.2001	−0.2001
a_{23}	0.2001	0.2001	0.2001	0.1334	0.1334	0.4668	0.1334	0.1334	−0.2001	−0.2001	−0.2001
a_{31}	0.2001	0.2001	0.2001	0.1334	0.1334	0.1334	0.4668	0.1334	−0.2001	−0.2001	−0.2001
a_{32}	0.2001	0.2001	0.2001	0.1334	0.1334	0.1334	0.1334	0.4668	−0.2001	−0.2001	−0.2001
b_{01}	−0.3646	−0.3646	−0.3162	−0.2001	−0.2001	−0.2001	−0.2001	−0.2001	0.3807	0.3485	0.2194
b_{02}	−0.6388	−0.6388	−0.5099	−0.2001	−0.2001	−0.2001	−0.2001	−0.2001	0.3485	0.9293	0.2517
b_{03}	−0.2355	−0.2355	−0.2839	−0.2001	−0.2001	−0.2001	−0.2001	−0.2001	0.2194	0.2517	0.3807

TABLE VIII

TIME TERMS

Location	From Cracovian	Using $v=6.0$	Setting $\alpha=0.5$	Originally assumed
a_{11}	$4.06-12.99/v-\alpha$	$1.90-\alpha\pm0.03$	1.40 ± 0.03	1.35
a_{12}	$7.51-32.99/v-\alpha$	$2.01-\alpha\pm0.03$	1.51 ± 0.03	1.49
a_{13}	$9.33-43.30/v-\alpha$	$2.11-\alpha\pm0.02$	1.61 ± 0.02	1.64
a_{21}	$14.08-73.34/v-\alpha$	$1.86-\alpha\pm0.02$	1.36 ± 0.02	1.35
a_{22}	$12.11-66.67/v-\alpha$	$1.00-\alpha\pm0.02$	0.50 ± 0.02	0.50
a_{23}	$11.01-60.01/v-\alpha$	$1.01-\alpha\pm0.02$	0.51 ± 0.02	0.50
a_{24}	$10.05-53.34/v-\alpha$	$1.16-\alpha\pm0.02$	0.66 ± 0.02	0.64
a_{25}	$9.05-46.67/v-\alpha$	$1.27-\alpha\pm0.02$	0.77 ± 0.02	0.78
a_{31}		$1.25-\alpha\pm0.05$	0.75 ± 0.05	0.78
a_{32}		$1.18-\alpha\pm0.05$	0.68 ± 0.05	0.64
a_{33}		$0.98-\alpha\pm0.05$	0.48 ± 0.05	0.50
a_{34}		$1.05-\alpha\pm0.05$	0.55 ± 0.05	0.50
b_{01}	$4.52-23.80/v+\alpha$	$0.55+\alpha\pm0.02$	1.05 ± 0.02	1.06
b_{02}	$8.77-50.28/v+\alpha$	$0.39+\alpha\pm0.03$	0.89 ± 0.03	0.92
b_{03}	$6.72-36.06/v+\alpha$	$0.71+\alpha\pm0.02$	1.21 ± 0.02	1.21
b_{29}		$-0.03+\alpha\pm0.05$	0.47 ± 0.05	0.50
b_{70}	$0 \quad +\alpha$	$0 \quad +\alpha$	0.50	0.50

It remains to estimate the arbitrary parameter α. We note that the computed time terms at the shot points 21, 22, 23, 33 and 34 are all approximately equal, and that setting $\alpha=0.5$ would produce equal values for stations 29 and 70. Further, we note that the same value of α makes the time terms at stations 01, 02 and 03 fit in smoothly with the constant rate of increase between shots 24

TABLE IX

THE COEFFICIENTS c AND d

Observation	c	d	δ
1101	+0.52	− 3.21	−0.02
1102	−0.53	+ 3.27	+0.01
1201	+0.57	− 3.21	+0.03
1202	−0.58	+ 3.27	−0.04
1301	+2.15	−12.90	0.00
1302	+1.10	− 6.42	+0.03
1303	−3.25	+19.36	−0.02
2101	+3.80	−22.86	−0.01
2103	+5.10	−30.60	0.00
2170	−8.88	+53.34	+0.01
2201	+1.57	− 9.53	−0.02
2203	+2.87	−17.27	−0.01
2270	−4.41	+26.67	+0.04
2301	−0.63	+ 3.81	+0.01
2303	+0.67	− 3.93	+0.01
2370	−0.01	+ 0.01	−0.01
2401	−2.87	+17.14	−0.02
2403	−1.57	+ 9.40	0.00
2470	+4.45	−26.66	+0.01
2501	−5.07	+30.47	+0.01
2503	−3.77	+22.73	0.02
2570	+8.85	−53.33	−0.04

and 25, and shots 11–13. This value of α yields the time terms shown in column 4 of Table VIII; these can be compared with the values that had originally been assumed in order to make up the travel-times. It is seen that the least squares method indeed yields values within the indicated magnitudes of error.

ACKNOWLEDGMENT

It is a pleasure for us to acknowledge the interest of Dr. Ian Halliday of the Dominion Observatory in our problem. Banachiewicz's Cracovian method, its inventor being an astronomer, has not heretofore found much application outside astronomy. We wish to thank Dr. Halliday for drawing our attention to it.

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COMMENTS ON "THE USE OF LEAST SQUARES METHOD FOR THE INTERPRETATION OF DATA FROM SEISMIC SURVEYS" BY A. E. SCHEIDEGGER AND P. L. WILLMORE

Some aspects of this paper were of special interest to me mainly because they called attention to an unfamiliar method. The triangular resolution method I find especially interesting.

However, I made a brief investigation of easily available literature, e.g., the article by G. E. Forsyth listed above and "Contributions to the Solution of Systems of Linear Equations and the Determination of Eigenvalues" edited by Olga Taussky, National Bureau of Standards, Applied Math. Series 39 (1954) especially the article by L. Fox, pages 26 and 47. Many square roots have to be extracted. There appear to be advantages in using the triangular resolution procedure for symmetric systems of equations such as those in the above paper. "Cracovians," I feel, are an unnecessary burden (not a heavy one, to be sure) and I prefer to use ordinary matrix notation which has become so familiar in the last 30 years in so many fields of applied mathematics. In my opinion the important thing in this paper is the triangular resolution and not the Cracovian method. I would replace (3.4) by $\boldsymbol{q}=\boldsymbol{p}^T\cdot\boldsymbol{p}$ where $\boldsymbol{p}^T$ is the transpose of the matrix, $\boldsymbol{p}$, obtained by changing rows of $\boldsymbol{p}$ into columns to get $\boldsymbol{p}^T$. Then the objective is to solve $\boldsymbol{q}\cdot\boldsymbol{x}=\boldsymbol{I}$ which is (2.3). Let $\boldsymbol{g}$ be the triangular matrix (g_{ij}) (with $g_{ij}=0$ when $j>i$). Then let $\boldsymbol{q}=\boldsymbol{g}^T\cdot\boldsymbol{g}$. We have to solve $\boldsymbol{g}^T\cdot\boldsymbol{g}\cdot\boldsymbol{x}=\boldsymbol{I}$. Let us first find $\boldsymbol{z}$ in $\boldsymbol{g}^T\cdot\boldsymbol{z}=\boldsymbol{I}$. This is

easily done. Then find x in $g \cdot x = z$ which is also easily done. Only the usual matrix multiplication rules are used.

For understanding the procedure the matrix method appears to me to have real advantages over the Cracovian method. For setting up the procedure of hand machine computing for an untrained operator, column by column (Cracovian) multiplication probably has advantages for the formation of the normal equations. The question is probably one of personal taste.

C. H. Dix

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VARIATION OF ELASTIC WAVE VELOCITIES IN BASIC IGNEOUS ROCKS WITH PRESSURE AND TEMPERATURE*

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ABSTRACT

The dilatational and rotational wave velocities have been measured as functions of pressure and temperature for three gabbros, two basalts and a dunite. The pressure range was 200–6,000 bars. The temperature range was 25° to 300°C. and 400°C. for one sample. The maximum pressure is equivalent to 23 km of depth and the highest temperature is believed to correspond to 25 km. The data indicate a tendency for the velocity to reach a maximum somewhere between 10 and 20 km and then decrease slightly.

INTRODUCTION

A method of measuring the dilatational or longitudinal wave velocities under high pressures and under temperatures up to 300°C. has been developed (Hughes and Jones, 1950; Hughes and Cross, 1951). This method applied to igneous rocks should be valuable in the investigation of some properties of the earth's crust. A study of elastic wave velocities in granites has already been carried out (Hughes and Maurette, 1956). The following work presents a similar investigation on basic igneous rocks, which are the most important constituents of the inner part of the earth's crust, below the granite layer and between the Conrad and Mohorovičič discontinuities. Measurements on a dunite have also been included, the dunite being believed to be the essential constituent of the earth's mantle below the Mohorovičič discontinuity.

The following rocks were selected: San Marcos Gabbro, Bytownite Gabbro, the Hornblende Gabbro, a basalt, the Analcime and a dunite from Jackson County, North Carolina.

APPARATUS AND METHOD

The apparatus is similar to that described by Hughes and Cross (1951) with the same modifications as those described by Hughes and Maurette (1956). The pressure range has been limited to 6,000 bars. The temperature range has been extended to 400°C. Dow Corning Silicone fluid D.C. 200 (3 centistokes viscosity) has been substituted for kerosene as the pressure transmitting fluid in order to reach temperatures above 300°C. Actually under high pressure the temperature was limited to 385°C. in order to prevent any permanent deformation of the pressure vessel. Another pressure vessel to be used soon should allow temperatures up to 500°C. The method of jacketing the sample is the same as that

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described in the previous article (Hughes and Maurette 1956). The method of measurement of the longitudinal and rotational velocities, V_D and V_R, is also the same: essentially, a sharp dilatational pulse is sent down a cylindrical sample. The receiving crystal picks up a first pulse which has traveled with the dilatational wave velocity and several delayed pulses, the arrivals of which are a function of the diameter of the rod, of V_D and V_R. This method then gives a direct measurement of both V_D and V_R (Hughes, Pondrom, and Mims, 1949). With coarse grained rocks the transformed wave arrivals are always very poor. In these cases y-cut crystals have been used in order to measure V_R directly. When V_R was measured by both methods, the agreement was fairly good (within 2 percent), the y-cut crystal value of V_R being generally higher than the x-cut crystal value.

RESULTS

Professor Clabaugh of the Geology Department of the University of Texas supplied the following description from an examination of thin sections:

San Marcos Gabbro from Escondido (California)

The rock has hyidiomorphic-granular texture which approaches ophitic texture. The average grain diameter is between 1 and 2 mm, and the minerals are fresh and unaltered. Labradorite makes up about 55 percent of the rock; the margins of most of the feldspar crystals have been changed to andesine by the action of late solutions. The dark minerals are chiefly hornblende and magnetite. Hornblende makes up about 35 percent of the rock, and a few of the crystals enclose cores of clinopyroxene. Part of the hornblende appears to have been formed by normal reaction of pyroxene and residual magma, part by later hydrothermal or deuteric reaction. Biotite, pyrite, pyrrhotite, and ilmenite are associated with the magnetite.

Bytownite Gabbro from Duluth (Minnesota)

The rock is coarse-grained and has ophitic texture. Many of the plagioclase crystals are 5 mm to 1 cm long, and their average thickness is about 2 mm. The plagioclase is either bytownite or calcic labradorite, and it constitutes about 70 percent of the rock. Olivine is the most abundant dark mineral, and the margins and fractured parts of the olivine grains are altered to chlorite, antigorite, and possibly talc. Augite and ilmenite or magnetite make up nearly 10 percent of the rock. Biotite and hornblende occur in small amounts with altered olivine; other minor accessory minerals include pyrite and apatite. Most of the plagioclase is unaltered except for chlorite-filled fractures, which are most numerous near the olivine grains. About 10 percent of the olivine has been replaced by secondary hydrous silicates.

Hornblende Gabbro

The rock has a hypidiomorphic-granular texture and the average grain diameter is between 0.5 and 1 mm. It is exceptionally fresh and unaltered. The most abundant mineral is plagioclase, which makes up about 40 percent of the

rock. The composition of the plagioclase is sodic labradorite near An_{58}, and it shows very minor zoning and numerous minute, dark inclusions. Hornblende makes up about 35 percent of the rock, pyroxene about 15 percent and biotite about 10 percent. The pyroxene is dominantly orthopyroxene, partly clinopyroxene, and it occurs as irregular, elongate remnants of nearly colorless crystals surrounded by the pale brownish-green hornblende. Biotite occurs in irregularly distributed clusters of crystals associated with 1 or 2 percent of magnetite and ilmenite. Pyrrhotite and apatite are minor accessory minerals.

Basalt

The rock is porphyritic, with plagioclase phenocrysts several mm long in an extremely fine-grained matrix in which plagioclase microlites are arranged in a well-developed flow pattern. The plagioclase appears to be labradorite, and it makes up more than half of the volume of the rock. The phenocrysts are crowded with small, dark inclusions of glass(?) or chloritic material(?) and many have patches of calcite, presumably filling gas cavities in the feldspar. A few darker phenocrysts appear to have been olivine crystals, now completely altered to calcite and antigorite(?) or chlorite(?). Magnetite and ilmenite are abundant, chiefly as minute grains in the matrix. The plagioclase microlites in the matrix are surrounded by glass which is crowded with dark crystallites and which includes altered greenish-brown ferromagnesian mineral grains, possibly altered pyroxene. Calcite fills a few cavities and is scattered throughout the rock in irregular patches.

This is the rock listed as hornblende basalt from Chaffee County, Colorado, but this specimen contains no hornblende, and specimens in our collections also lack hornblende. The rocks show considerable alteration, and it is not a typical basalt, because it lacks the quantity of pyroxene and olivine normally found in basalts.

Analcime-bearing labradorite trachyte

The rock is holocrystalline and porphyritic with a very fine-grained matrix which has an average grain diameter of about 0.1 mm. The phenocrysts are pale green aegiritic clinopyroxene and plagioclase rimmed with alkali feldspar. In the matrix plagioclase (labradorite) forms the cores of many alkali feldspar crystals, and analcime occurs in small angular patches between the feldspar crystals. Scattered grains of olivine are mostly altered to dark greenish brown antigorite. Alkali feldspar (anorthoclase or sodic sanidine) makes up about 60 percent of the rock, labradorite about 15 to 20 percent, and pyroxene about 10 to 15 percent. Analcime may amount to as much as 5 percent and magnetite and ilmenite to 2 or 3 percent. Biotite, apatite, and olivine are present in smaller amounts.

The rock is an unusual one, similar to some of those found in the alkali rich complexes along the front ranges of the Rocky Mountains from western Texas to Montana. These rare, alkali-rich rocks are almost insignificant in volume when compared with basalt and granite in the crust of the earth.

Dunite, (Jackson County, North Carolina)

The rock has the peculiar granular texture of many dunites in which anhedral olivine grains ranging in size from less than ½ mm diameter to more than 1 cm diameter are packed together. Olivine makes up more than 99 percent of the rock, and it is fresh and unaltered except for traces of secondary minerals along some of the fractures. Chromite is scattered through the rock in minute flakes and crystals.

Macroscopic: Light green, granular rock composed almost entirely of glassy olivine with small black grains of chromite and a few muscovite flakes of considerable size.

Microscopic: The slide is composed of a mosaic of clear olivine grains. A small amount of serpentine occurs in the cracks of the olivine. Stringers of carbonate, probably dolomite, wind across the section. Crystal and grains of chromite are slightly transparent and brown on the edges. Flakes of chlorite with anomalous brown interference colors are associated with the chromite. A small amount of fibrous cummingtonite may also be seen.

The results are presented in Tables I-VI. In every case except the dunite, the changes in velocity with temperature are very small for the 25°–100°C. range and also in some cases in the 25°–200°C. range. The pressure tends to smooth out the temperature effect: for the San Marcos Gabbro the relative decrease of V_D (from the 25°C. value) at 1,000 bars is 2.3 percent at 300°C. and 16 percent at 400°C. At 6,000 bars these decreases are reduced to .7 percent at 300°C. and 4.3 percent at 400°C. In most of the cases and above 1,000 bars, V_R is practically independent of pressure and varies very little with temperature up to 300°C. Except for the 400°C. run, after which the room tempearture values of V_D decreased slightly (less than 2 percent), heating the rocks did not affect their room temperature properties. In order to preserve the room temperature properties of the rocks, the pressure was never lowered below 500 bars when the samples were at 200°C. or above. (See Hughes and Maurette, 1956.)

TABLE I

SAN MARCOS GABBRO
Velocities in km/sec

Density: 2.993 gm/cm³

P bars	25°C.		100°C.		200°C.		300°C.		400°C.	
	V_D	V_R	V_D	V_R	V_D	V_R	V_D	V_R	V_D	V_R
200	6.69	3.47	6.63	3.43						
500	6.79	3.48	6.78	3.50	6.75	3.48	6.53	3.35		
1,000	6.88	3.50	6.87	3.51	6.87	3.50	6.72	3.46	5.78	2.91
1,500	6.93	3.50	6.92	3.52	6.92	3.51	6.80	3.48	6.09	3.05
2,000	6.95	3.51	6.94	3.53	6.94	3.52	6.86	3.50	6.29	3.25
3,000	6.98	3.51	6.97	3.53	6.97	3.53	6.93	3.51	6.49	3.39
4,000	7.01	3.52	6.98	3.53	6.99	3.53	6.95	3.52	6.62	3.42
5,000	7.03	3.53	7.00	3.53	7.00	3.53	6.97	3.52	6.69	3.42
6,000	7.05	3.54	7.02	3.54	7.01	3.54	7.00	3.52		

TABLE II

BYTOWNITE GABBRO
Velocities in km/sec

Density: 2.885 gm/cm³

P bars	25°C.		100°C.		200°C.		300°C.	
	V_D	V_R	V_D	V_R	V_D	V_R	V_D	V_R
200	6.45	3.42	6.42					
500	6.61	3.45	6.56	3.40	6.37	3.35	5.96	3.25
1,000	6.69	3.47	6.60	3.42	6.47	3.39	6.13	3.32
1,500	6.72	3.51	6.64	3.43	6.53	3.41	6.27	3.36
2,000	6.76	3.52	6.68	3.45	6.57	3.44	6.35	3.39
3,000	6.78	3.52	6.72	3.46	6.62	3.45	6.45	3.42
4,000	6.81	3.53	6.73	3.48	6.64	3.46	6.52	3.44
5,000	6.83	3.53	6.76	3.49	6.67	3.47	6.57	3.45
6,000	6.84	3.54	6.79	3.50				

TABLE III

HORNBLENDE GABBRO
Velocities in km/sec

Density: 2.933 gm/cm³

P bars	25°C.		100°C.		200°C.		300°C.	
	V_D	V_R	V_D	V_R	V_D	V_R	V_D	V_R
200	6.60	3.56	6.56	3.57				
500	6.67	3.59	6.63	3.62	6.49	3.55	6.14	3.44
1,000	6.74	3.65	6.69	3.64	6.61	3.60	6.44	3.51
1,500	6.78	3.66	6.74	3.67	6.69	3.63	6.56	3.55
2,000	6.80	3.69	6.77	3.69	6.73	3.65	6.64	3.59
3,000	6.84	3.71	6.81	3.70	6.77	3.67	6.70	3.64
4,000	6.86	3.71	6.85	3.71	6.82	3.71	6.76	3.68
5,000	6.88	3.71	6.87	3.72	6.83	3.73	6.78	3.71
6,000	6.89	3.72	6.88	3.71	6.84	3.74	6.81	3.71

TABLE IV

ANALCIME
Velocities in km/sec

Density: 2.712 gm/cm³

P bars	25°C.		100°C.		200°C.		300°C.	
	V_D	V_R	V_D	V_R	V_D	V_R	V_D	V_R
200	5.41	3.05	5.35	3.01				
500	5.48	3.08	5.42	3.05	5.33	3.03	5.10	2.86
1,000	5.55	3.09	5.50	3.06	5.42	3.06	5.25	2.92
1,500	5.62	3.10	5.56	3.07	5.49	3.07	5.37	2.97
2,000	5.67	3.10	5.59	3.08	5.55	3.08	5.44	2.99
3,000	5.73	3.11	5.66	3.10	5.65	3.08	5.55	3.02
4,000	5.76	3.11	5.69	3.11	5.68	3.10	5.62	3.05
5,000	5.78	3.11	5.72	3.11	5.71	3.11	5.65	3.07

Table VI gives the values of velocities for the dunite. These values seem low and unfortunately the runs could not be repeated on this sample. Thus, these data should be suspected as being in error.

TABLE V

BASALT
Velocities in km/sec

Density: 2.586 gm/cm³

P bars	25°C.		100°C.		200°C.		300°C.	
	V_D	V_R	V_D	V_R	V_D	V_R	V_D	V_R
200	5.41	3.21						
500	5.57	3.23	5.59	3.20	5.50	3.18	5.40	3.16
1,000	5.66	3.25	5.67	3.21	5.59	3.20	5.44	3.17
1,500	5.73	3.26	5.71	3.22	5.65	3.21	5.50	3.18
2,000	5.75	3.26	5.75	3.23	5.71	3.22	5.58	3.20
3,000	5.79	3.26	5.78	3.24	5.77	3.23	5.69	3.22
4,000	5.80	3.27	5.79	3.24	5.80	3.24	5.79	3.23
5,000	5.81	3.27	5.80	3.23	5.81	3.24	5.82	3.24
6,000	5.82	3.27	5.81	3.23	5.82	3.24	5.83	3.24

DISTRIBUTION OF VELOCITIES IN DEPTH

Table VII shows the values of V_D, V_R and Poisson's ratio σ to be expected at various depths. In order to determine their values a careful computation of the temperature gradient in the earth's crust has been carried out. The heat generated by radioactive decay in the earth's crust was found to amount to 70 percent of the total heat flowing through the surface of the earth. Out of this 70 percent, 50 percent is generated in the granite layer and 20 percent in the basic layer. By taking this fact into account and by assuming a uniform distribution of radioactive heat generation within a layer, the temperature gradient is found to decrease linearly with depth within the granitic layer and within the basic layer, at a different rate in each layer. The temperature gradients computed are:

In the granitic layer ($0 < X < 15$ km)

$$G_g = (24.8 - 0.9X)\ ^\circ\text{C/km}$$

In the basic layer ($15\text{ km} < X < 35$ km)

$$G_b = [13 - 0.26(X - 15)]\ ^\circ\text{C/km},$$

X being the depth in kilometers.

TABLE VI

DUNITE
Velocities in km/sec

Density: 3.198 gm/cm³

P bars	25°C.		100°C.		200°C.	
	V_D	V_R	V_D	V_R	V_D	V_R
200	7.40	3.79	7.15	3.69		
500	7.54	3.88	7.38	3.83	6.78	3.50
1,000	7.63	3.99	7.54	3.88	6.97	3.54
1,500	7.70	4.09	7.63	3.97	7.06	3.56
2,000	7.77	4.10	7.69	4.05	7.13	3.63
3,000	7.82	4.13	7.77	4.07	7.28	3.72
4,000	7.86	4.15	7.83	4.11	7.40	3.79
5,000	7.91	4.17	7.86	4.12	7.43	3.83

TABLE VII

V_D, V_R, σ, VS DEPTH IN BASIC IGNEOUS ROCKS

Depth (km)		1	2	5	10	15	20	25
Temperature °C.		45	70	135	225	290	350	400
Pressure (bars)		260	520	1,300	2,600	3,900	5,300	6,700
San Marcos Gabbro	V_D	6.70	6.79	6.90	6.96	6.95	6.88	6.80
	V_R	3.47	3.49	3.51	3.52	3.51	3.47	3.44
	σ	.317	.320	.325	.328	.329	.329	.328
Bytownite Gabbro	V_D	6.50	6.56	6.60	6.57	6.53		
	V_R	3.41	3.42	3.42	3.44	3.43		
	σ	.310	.313	.316	.311	.309		
Hornblende Gabbro	V_D	6.60	6.65	6.71	6.74	6.75		
	V_R	3.57	3.60	3.64	3.69	3.68		
	σ	.293	.293	.291	.286	.289		
Analcime	V_D	5.41	5.45	5.51	5.59	5.62		
	V_R	3.05	3.06	3.07	3.07	3.05		
	σ	.267	.270	.275	.284	.291		
Basalt	V_D	5.44	5.58	5.68	5.74	5.79		
	V_R	3.21	3.21	3.22	3.23	3.23		
	σ	.233	.253	.263	.269	.274		
Dunite	V_D	7.35	7.46	7.50	7.22			
	V_R	3.77	3.85	3.90	3.68			
	σ	.321	.319	.315	.324			

The computations were based upon the following values of the parameters involved: heat flow on the surface: 47 calories per cm² per year (Birch 1942, page 269, Revelle 1954, page 323). Thermal conductivity: granites: 6.0×10^{-3} cal per cm per sec per °C.; basic igneous rocks: 5.5×10^{-3} cal per cm per sec per °C. (Birch 1942, page 251).

TABLE VIII

V_D, V_R, σ VS DEPTH IN GRANITES

Depth (km)		1	2	5	10	15
Temperature (°C.)		45	70	135	225	290
Pressure (bars)		260	520	1,300	2,600	3,900
Texas Gray	V_D	5.90	6.00	6.02	6.02	6.01
	V_R	3.45	3.55	3.57	3.57	3.57
	σ	.240	.231	.229	.229	.227
Texas Pink	V_D	6.08	6.24	6.32	6.30	6.27
	V_R	3.29	3.32	3.32	3.32	
	σ	.293	.303	.309	.308	
Woodbury	V_D	5.90	6.05	6.15	6.14	6.04
	V_R	3.34	3.43	3.54	3.61	
	σ	.264	.263	.252	.236	

TABLE IX

ELASTIC MODULI AT VARIOUS PRESSURES AND TEMPERATURES

μ = Shear modulus in 10^5 bars
E = Young's modulus in 10^5 bars
K = Bulk modulus in 10^5 bars

		25°C.		300°C.	
		500 bars	5,000 bars	500 bars	5,000 bars
San Marcos Gabbro	μ	3.63	3.75	3.34	3.70
	E	9.60	9.98	8.83	9.83
	K	8.99	9.84	8.27	9.58
Bytownite Gabbro	μ	3.43	3.62	3.03	3.44
	E	9.01	9.53	7.81	9.01
	K	8.07	8.68	6.17	7.86
Hornblende Gabbro	μ	3.78	4.07	3.45	4.03
	E	9.81	10.54	8.78	10.37
	K	8.05	8.57	6.42	8.11
Analcime	μ	2.58	2.65	2.22	2.56
	E	6.54	6.87	5.64	6.61
	K	4.70	5.64	4.09	5.27
Basalt	μ	2.71	2.79	2.57	2.73
	E	6.75	7.08	6.37	6.97
	K	4.43	5.11	4.08	5.19
Dunite	μ	4.82	5.57		
	E	12.72	14.57		
	K	11.78	12.65		

Radioactive heat generation: in granites 6.6×10^{-6} cal per gram per year; in basic rocks 1.6×10^{-6} cal per gram per year (Birch, 1951). Average earth's crust composition: sedimentary rocks: from 0 to 1 km; granite rocks from 1 km to 15 km; basic igneous rocks from 15 km to 35 km (Revelle 1954, page 323). The pressure gradient was taken to be 260 bars per kilometer in the granite layer and 280 bars per kilometer in the basic layer. With these values of the temperature and pressure gradients the maximum temperature obtained, 400°C., corresponds to 25 km. The temperature of 300°C. corresponds to 16 km. and the maximum pressure corresponds to 23 km.

In Table VIII we give the elastic wave velocities and Poisson's ratios to be expected at various depths for Texas Pink, Texas Gray, and Woodbury Granites. These data represent a correction of those published recently by the authors (Hughes and Maurette 1956). The initial values had been computed assuming a constant temperature gradient (24°C.) and a slight error in the pressure gradient.

Both Tables VII and VIII show that the seismic velocities in igneous rocks go through a maximum at a relatively shallow depth. This maximum is located around 5 km to 10 km in the granites, around 15 km in basalts, and between 5

km and 15 km in gabbros. From the values of V_D and V_R one may compute the elastic moduli, the rocks being assumed isotropic. Table IX shows the values of the shear modulus μ, Young's modulus E and bulk modulus K at 25°C. and 300°C. under low and high pressure: 500 bars and 6,000 bars.

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GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 32-47, 10 FIGS.

EXPLORING FOR ANCIENT CHANNELS WITH THE REFRACTION SEISMOGRAPH*

L. C. PAKISER† AND R. A. BLACK†

ABSTRACT

In the Monument Valley of Arizona and Utah, uranium ore has been found in ancient channel deposits, primarily in the Shinarump member of the Chinle formation of Late Triassic age. The seismic velocity in the Shinarump member is substantially less than that in the Moenkopi formation of Early and Middle(?) Triassic age, which unconformably underlies the Shinarump. Therefore, the ancient channels can be located by using the refraction seismograph. Because the erosion surface of the Moenkopi in channel areas is curved, a delay-time method of analysis is used to determine the position in depth of the Shinarump and Moenkopi contact. The problem of velocity variations within the Shinarump can be largely overcome by careful interpretation supported by drill-hole and velocity control.

INTRODUCTION

In the Monument Valley of Arizona and Utah uranium ore has been found in ancient channel deposits. Stream channels cut into the Moenkopi formation of Early and Middle(?) Triassic age were filled with the basal sediments of the Shinarump member of the Chinle formation of Late Triassic age and subsequently the Moenkopi formation was buried under the Shinarump member and younger sedimentary rocks. It is in these channel sediments of the Shinarump that the uranium ore was deposited. Not all of these ancient channels contain mineralized zones and mineralized zones may be sporadic along any channel trend. However, the discovery of a channel is the first step in finding uranium ore in this area. If channels can be discovered economically by geophysical means, costs of exploratory drilling can be sharply reduced.

The seismic velocity in the coarse clastic rocks of the Shinarump member is substantially less than that in the underlying shales and mudstones of the Moenkopi formation, so that where the Shinarump is exposed at the surface or covered by a few feet of surficial deposits the unconformity on the surface of the Moenkopi can be mapped with the refraction seismograph. Special problems in refraction shooting arise, however, where the mudstones of the Chinle formation of Late Triassic age overlie the Shinarump member. The velocities in these mudstones in many places exceed that of the Shinarump member and may approach that of the Moenkopi. However, recent experience has shown that a relatively thin section of weathered mudstones of the Chinle overlying the Shinarump may not seriously hamper seismic refraction operations.

Wantland and Casey of the U. S. Bureau of Reclamation conducted the first seismic refraction work in Monument Valley at Nokai Mesa, along the Arizona-Utah border in the Navajo Indian Reservation, during August and September

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1952 (Wantland and Casey, 1952; Wantland, 1954). They were able to map a large channel without difficulty and their results agreed closely with the drill-hole control.

The U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission began exploring for ancient channels in a number of areas in Monument Valley in the summer of 1953. In most of these areas the Shinarump and Moenkopi contact was successfully mapped, but many problems not present at Nokai Mesa had to be considered during the course of these later investigations. These problems include: (1) velocity variations in the Shinarump member, particularly the presence of high-velocity mudstone lenses; (2) velocity variations in the Moenkopi formation; and (3) irregularly curved refracting surfaces requiring special interpretation methods. Many of these problems have been successfully overcome and the seismic refraction method has been established as the most useful geophysical tool yet available in locating ancient buried channels.

This paper illustrates some of these problems and presents a method of interpreting traveltime curves in channel areas.

LOCATION AND GEOLOGY

The places in which the refraction seismograph has been used to explore for ancient channels in the Monument Valley area of Utah and Arizona are shown in Figure 1. The Monument Valley area of southern Utah is bounded by the 110th meridian on the east, the San Juan River on the north, Copper Canyon on the west, and the Utah-Arizona state line on the south. In Arizona, the Monument Valley area includes the Boot Mesa, Agathla Peak, and Garnet Ridge 15-minute quadrangles. The Monument Valley area can be reached by Utah State Highway 47 from the north and by various roads through the Navajo Indian Reservation from the south.

The main structural feature of the Monument Valley area is the Monument Upwarp, which trends approximately north , and extends from Kayenta, Arizona, to the junction of the Green and Colorado Rivers in Utah. The Monument Upwarp is a broad, flattened anticline with associated subordinate folds which are usually asymmetrical. Two of these subordinate features are the Oljeto syncline and the Organ Rock anticline (Fig. 1).

The axis of the Oljeto syncline approximately follows the course of Oljeto Wash, and the west limb of the syncline (the Hoskinini monocline) rises steeply to the Organ Rock anticline, which roughly parallels the Oljeto syncline.

In Monument Valley the exposed, consolidated, sedimentary rocks range in age from Permian to Jurassic, and their total thickness may be as much as 8,000 feet (Baker, 1936). Uranium deposits are found in many places in the Shinarump member of the Chinle formation of Late Triassic age. The Shinarump member in the Monument Valley area ranges in composition from a coarse basal conglomerate to a medium- to coarse-grained sandstone in the upper part. The light-

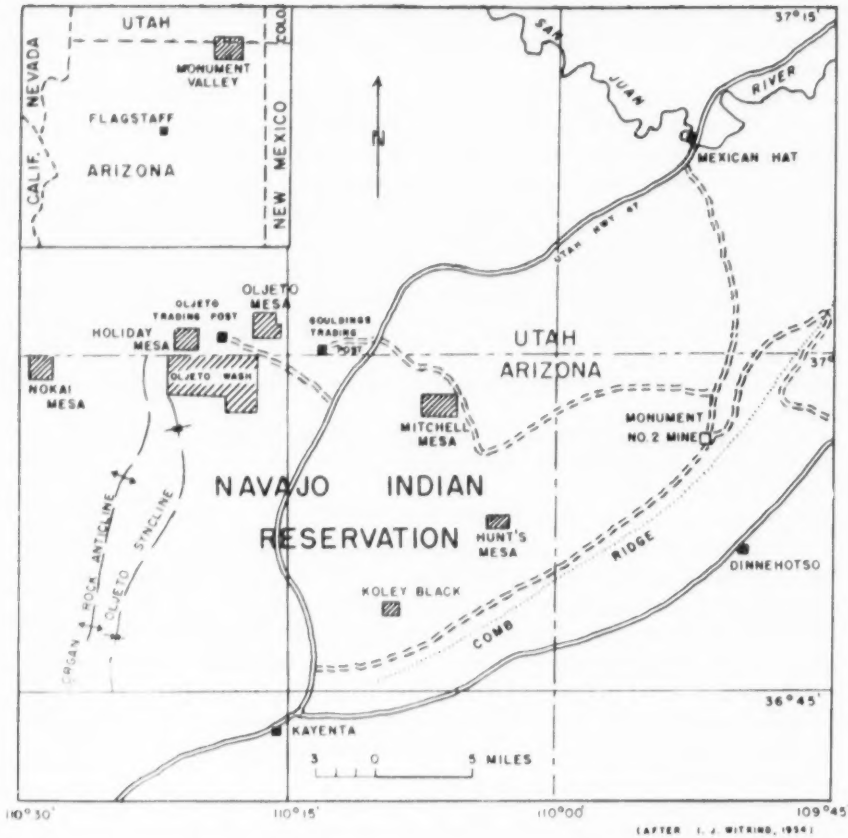


FIG. 1. Map of part of Monument Valley area showing locations of refraction seismograph surveys.

gray or buff sandstone and conglomerate of the Shinarump grade into each other and are in many places cross bedded. The Shinarump contains considerable quantities of silicified wood and some black carbonaceous material. Mudstone lenses are common in the Shinarump; these lenses range in thickness from a few inches to as much as 10 feet and may have a considerable lateral extent. In the Monument Valley area, the thickness of the Shinarump ranges from a few feet to 200 feet or more in the deeper channel troughs.

The Shinarump member of the Chinle formation is underlain by the Moenkopi formation of Early and Middle(?) Triassic age. The Moenkopi is composed of dark-brown to red-brown thin, evenly bedded, sandy shales and thin, ripple-marked sandstones.

The contact between the Shinarump and the Moenkopi is a widespread unconformity marked by contrasting textures and rock compositions. In places, the Shinarump and Moenkopi contact is marked by channels that were cut into the Moenkopi formation prior to or during the deposition of the Shinarump sediments. These buried stream channels are, at the present time, the main guide to uranium ore deposits in the Shinarump. All of the uranium deposits in the Shinarump of the Monument Valley area have been found in these buried channels, but not all channels contain mineralized zones.

These ancient buried channels in the Monument Valley area range in size from 10–20 feet wide and 5–10 feet deep to 200–2,000 feet wide and 70–200 feet deep.

FIELD METHODS

The Shinarump member of the Chinle formation in the areas included in this discussion ranges in thickness from a few feet to 200 feet. If the velocity contrast between the Moenkopi formation and Shinarump member is, on the average, 2 to 1, the total length of an individual spread should be about seven times the depth, so that the critical distance will be about one-half the total spread length or less. The most generally useful spread length is 550 feet, but spreads 1,100 feet long are used for the greater thicknesses of Shinarump; shorter spreads may be used where the Shinarump is very thin. In reconnaissance profiling, spreads are placed end to end; but, when channel areas are detailed, each succeeding spread overlaps the preceding one by 50 percent. Dynamite charges are fired at both ends of each spread. When drill holes are available, inhole velocity surveys, using detectors lowered into the drill-holes, are made to provide reliable vertical velocities.

Conventional 12-channel portable refraction seismic instruments, usually mounted in a light four-wheel drive vehicle, and conventional inline geophone spreads are used. Charges are fired both in the air and in shallow shot holes. The U. S. Geological Survey has used shovels and hand augers to dig shot holes, with dirt tamping; a jack-hammer was used by the Bureau of Reclamation. Although smaller charges can be used in shot holes, air shooting with single elevated charges has been used almost exclusively by the U. S. Geological Survey (with no loss in record quality) because of the saving in time and the elimination of much of the flying debris that accompanies refraction shooting in shallow holes. The area is thinly populated and air shooting brings few protests.

Charges of from 2½ to 10 pounds of 60-percent gelatin dynamite are fired from steel poles 3 to 6 feet high. Wooden blocks 2 inches square in cross section are used to prevent damage to the shooting poles. Holes are drilled in the blocks so that they will slide over the top of the steel pole and over ½-inch sharpened wooden dowels on which the dynamite charges are placed. The charges are fired from a distance of about 200-300 feet after all metal bands have been removed from the dynamite. Small fragments of cap wire may be thrown for considerable distances and may cut cables placed too near a shot point. Safety precautions include use of safety hats for exposed field personnel, hanging the cap wire so that it will be

blown away from the instrument truck, and placing the instrument truck between field personnel and the shot point.

Shot point and geophone locations and elevations must be determined by plane table or transit surveys.

A typical seismic refraction crew consists of partychief-interpreter, observer-shooter, surveyor, and three or four laborers.

INTERPRETATION

The classical methods of interpreting seismic refraction traveltime curves based on critical distance and intercept-time formulas, as outlined in the standard geophysical textbooks, give misleading results in interpreting channel structures in Monument Valley. The erosional surface on the Moenkopi is not a plane surface; it is most irregular in the channel areas of greatest interest. The width of many (probably most) channels is less than a typical spread length, so the refracting interface must be considered as a curved surface. High-velocity mudstone lenses within the Shinarump in many places preclude accurate determination of the velocity in the Shinarump because the V_1 (Shinarump) part of the traveltime curves will then represent, in whole or in part, the velocity in the mudstone and not the average velocity in the Shinarump; if thin lenses extend over entire spread lengths, use of the higher velocity in depth computations will give erroneous depths. This is the familiar problem of velocity inversion. Lateral and vertical variations in the velocity in the Shinarump, caused by changes in the physical properties of the sandstone, also complicate the problem and require fairly close drill-hole control and velocity logging for complete interpretation. An increase in velocity is usually associated with thickening of the Shinarump.

Corrections

Routine weathering corrections should be made but this is seldom possible. The base of the weathered layer in Monument Valley is an indefinite boundary between the unweathered Shinarump at rather shallow depths and the overlying aerated Shinarump and residual or windblown soil. The water table is generally at very great depths, well below the Shinarump and Moenkopi contact. The weathered layer velocities are very low, in places 500 fps or less, so minor variations in the thickness of the weathered layer cause large arrival-time delays. It is seldom possible to make routine weathering corrections, however, because high-velocity mudstone lenses and other velocity variations in the Shinarump interrupt the continuity of the V_1 (Shinarump) segments of the traveltime curves. Thus, the recognition of variations in the thickness of the weathered layer, as opposed to variations in the depth to the Moenkopi, becomes a problem which is inseparable from the over-all process of interpretation.

Arrival-time delays on the V_1 segment of a traveltime curve which are duplicated on the overlapping V_2 (Moenkopi) segment from the reversed shot can be identified as weathered-layer time delays. However, high-velocity mudstone

traveltime segments at short distances from the shot point may make this distinction impossible. In such places, the arrival-time delays are revealed only on the V_2 segment, and they could be caused by variations in either the thickness of the weathered layer or in the depth to the Moenkopi. Time variations caused by changes in the depth to the Moenkopi, however, will be displaced from the depth point away from the shot point on each of the reversed shots, and they will not coincide. Time variations caused by changes in the thickness of the weathered layer will coincide in horizontal position.

Elevation corrections are not made in the conventional manner for it is usually impossible to choose a flat datum that will be valid for any considerable distance. Computed depths are plotted on cross sections below the surface (or subweathering) elevations so that, in effect, elevation corrections are made graphically.

A typical manifestation of a thin mudstone lens within the Shinarump member is shown in Figure 2. The difference between arrival-time variations caused by variations in the thickness of the weathered layer and those caused by changes in the depth to the Moenkopi formation is illustrated by Figure 3.

Delay-time analysis

A modification of an interpretation procedure suggested by Barthelmes (Barthelmes, 1946; Dobrin, 1952, p. 237–240) is used in interpreting the curved refracting surfaces in channel areas. However, the classical refraction formulas

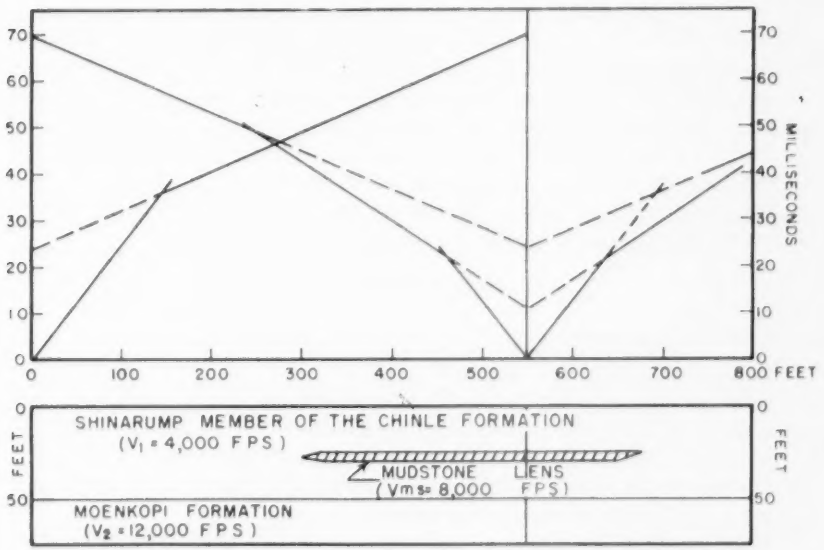


FIG. 2. Effect of a mudstone lens on traveltime curves.

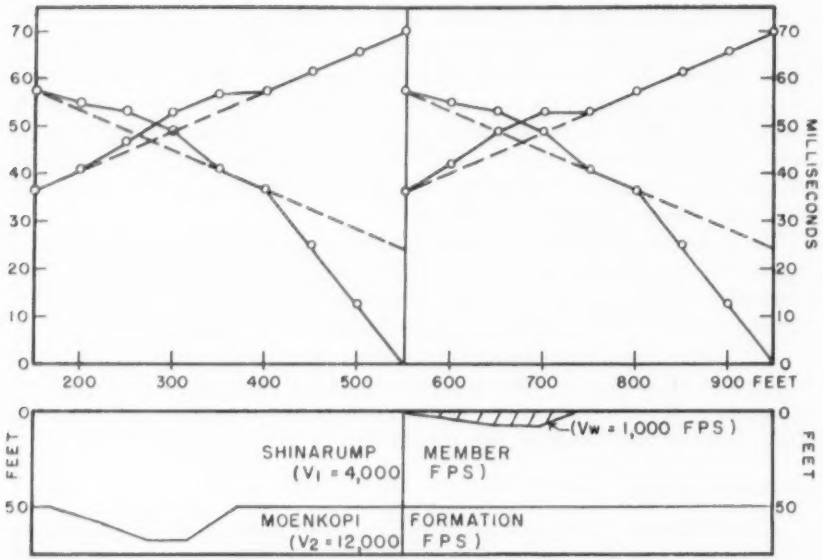


FIG. 3. Effects of channel and change in weathered-layer thickness on traveltime curves.

can be used for preliminary analyses of refraction traveltime curves in Monument Valley. The procedure used involves calculating the delay time for each geophone and treating delay-time variations as resulting from variations in the depth of the refractor. The delay time has been defined as the additional time required for a wave to travel any segment of a ray trajectory over the time that would be required for a wave to travel the horizontal component of that segment at the highest velocity reached by the trajectory (Nettleton, 1940, p. 250).

For a two-layer case without dip, the time taken by a wave to travel from the shot point to any detector beyond the critical distance is:

$$t = x/V_2 + (2z \cos i)/V_1,$$

where

x is the horizontal distance from the shot point to the detector,
V_1 is the velocity of the overburden,
V_2 is the velocity of the deeper, high-velocity, layer,
z is the depth to the high-velocity layer, and
i is the critical angle of incidence ($\sin i = V_1/V_2$).

The sum of the delay times terminating at the shot point and any detector is $(2z \cos i)/V_1$. This is identical to the intercept time ($x = 0$).

If the depths at the shot point and detector, because of either dip or surface elevation changes, are not equal, the traveltime from the shot point to any de-

tector becomes:

$$t = x/V_2 + (z_s \cos i)/V_1 + (z_d \cos i)/V_1 \text{ (approximately)},$$

where z_s and z_d are the vertical depths below the shot point and detector respectively.[1]

The latter two terms of the equation are the delay times for the shot point and detector respectively. Therefore, the sum of the delay times for the shot point and any detector can be determined by subtracting x/V_2 from the detector arrival times. Because the delay time for the shot point remains constant for any spread, any variations in the delay time for detectors are proportional to variations in depths to the refractor beneath those detectors. The depth variation between any two detectors is:

$$\Delta z_d = (\Delta t_D V_1)/\cos i,$$

where Δt_D is the difference in delay times between the two detectors. The depth point is not directly below the detector, however, but (ignoring dip) is displaced toward the shot point by:

$$\Delta x = z_d \tan i.^2$$

Thus it is possible to calculate the total delay time for the shot point and detector for each detector position and to calculate from those total delay times the depth variations. If the depth at any point is known (from a drill hole) or can be calculated at any shot point by the classical refraction formulas (that is, where the refractor is a plane surface), the depth at any other point can be determined by adding or subtracting the appropriate depth variation.

The following relationships also apply:

The delay times are equal for opposite ends of a reversed spread—that is, if the end detector is placed at the opposite shot point, $t - x/V_2$ will be identical for waves traveling from opposite ends of the spread because identical paths have been traveled.

The difference in delay times for waves arriving at any detector from two different shot points (usually, but not always, from opposite ends of a spread) is proportional to the difference in depth between the two shot points, or

$$\Delta z_s = (\Delta t_D V_1)/\cos i.$$

This is true because the delay times for the detector location are identical.

The errors resulting from neglecting dip in the above relationships are negligible for dips of up to 10 degrees; they are not serious for dips as great as 25 degrees, considering the uncertainties from other sources of error.

[1] The exact form of this equation is

$$t = [x/V_2 + (z_s \cos i)/V_1 + (z_d \cos i)/V_1] \cos \theta,$$

where θ is the angle of dip.

[2] The exact form of this equation is $\Delta x = z_d \cos \theta \sin (i \pm \theta)/\cos i$ and the depth below the migrated position is $z_d \pm \Delta x \tan \theta$.

Procedure

The delay time method is used in practice in the manner described below (Fig. 4).

1. Plot the traveltime curves for opposite ends of a reversed spread in the usual manner.

2. Through the origin, at each end of the spread, construct a line whose inverse slope is equal to the known velocity of the high-velocity refractor. This velocity can be determined from traveltime curves in an area where the surface of the refractor is a plane surface.

3. Scale the time difference between each arrival time (beyond the critical distance) and the corresponding position on the sloping line constructed in step

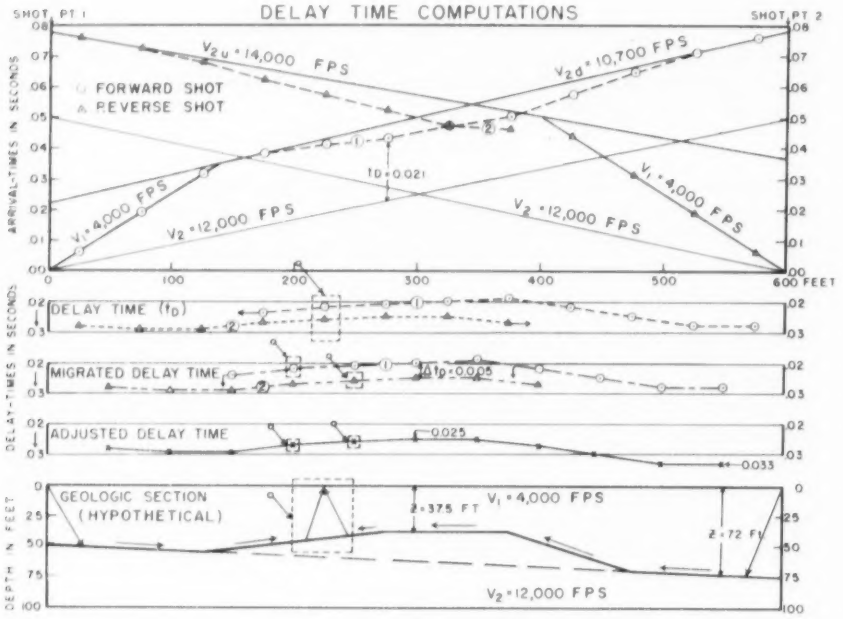


FIG. 4. Graphical delay time analysis.

2, above. This is the total delay time and this step is equivalent to subtracting x/V_2 from the detector arrival times. The total delay time is equal to the sum of the delay times for the segments terminating at the shot point and detector.

4. Plot the total delay time so determined beneath each detector position. Note that the time scale for delay times increases downward so that increases in depth are shown by downward deflections of the delay-time curve.

5. Migrate the position of the delay time for each detector position toward the shot point by:

$$\Delta x = z \tan i.$$

Actually, the amount of migration will change for each detector position if the depth changes. However, if the depth changes are not extreme, no great error will be introduced if an average depth is assumed and all delay times are migrated the same distance on the same spread. The migrated delay times obtained from a shot point at one end of a spread will not be the same as those obtained from the shot point at the other end of the spread; they will differ by a constant amount that is proportional to the difference in depth of the refractor below the shot points.

6. Scale and average the delay-time differences for the forward and reverse shot for each detector position. Adjust the delay-time curve by shifting one overlapping delay-time curve upward or downward by this difference. The overlapping part of the two delay-time curves should now coincide if the right velocity has been chosen. If it does not coincide, individual discrepancies should be averaged out; weathered layer effects and delay-time variations caused by local elevation irregularities should be removed. This process of shifting and averaging can be continued for any number of delay-time curves overlapping each other. The delay-time difference for waves traveling in the zone of overlap to a detector position from any two shot points, regardless of their directions or distances, from the detector, will be proportional to the difference in depth between the two shot points.

7. Choose any point on the adjusted delay-time curve as a datum, preferably a point at which the depth is known or can be easily determined. Determine the delay-time difference of each detector position from this datum and calculate the corresponding depth difference from:

$$\Delta z_d = \Delta t_D V_1 / \cos i.$$

The true depth for each detector position can then be determined by adding or subtracting this depth difference from the known depth. Even in the event that there is no known depth, or the traveltime curves are so irregular that a plane portion cannot be selected for a reliable computed depth, depth differences computed from the delay-time differences will yield reliable relative depths.

8. Plot the depth or relative depth below the surface elevation at the appropriate detector position.

Figure 4 shows this process in its entirety. Note how the total delay time (t_D) of 0.021 second is determined by scaling the time difference between the arrival time and the 12,000 fps line below. The delay times are shifted in the directions of the horizontal arrows to get the migrated delay-time curves. One migrated delay-time curve (marked 1) is shifted downward by 0.005 second to get the adjusted delay-time curve, and it now coincides with the migrated delay-time curve from the opposite shot point (marked 2).

The adjusted delay time for the detector nearest Shot Point 2 is 0.033 second. This is established as the datum. The delay-time differences from 0.033 are determined and from them the depth differences are calculated. These depth differences can then be added to the "known" depth of 72 feet near Shot Point 2, but this step is not shown because it would unnecessarily complicate the figure.

It is seen that the errors involved in the assumption that all delay times can be migrated by the same amount and that the dip can be neglected are not great. The hypothetical geologic section from which the traveltime curves were derived and the adjusted delay-time curve have the same appearance. The sharp changes in slope are smoothed out somewhat on the adjusted delay-time curve.

Checking delay-time curves

The graphical delay-time interpretation method just described includes many approximations but it is possible to control the over-all accuracy of the final delay-time curve rather closely by the following checks:

1. The delay times for opposite ends of a reversed spread should be equal.
2. The difference in delay times for any detector for different shot points is proportional to the difference in depth of the high-speed refractor between the two shot points.
3. If overlapping delay-time curves are not parallel, the assumed high velocity is in error and it can be corrected. Variations in the velocity of the high-velocity layer (Moenkopi) can be detected by this means.
4. The difference in time on the adjusted delay-time curve between any two shot points must be equal to the difference in delay times of the overlapping migrated delay-time curves for those two shot points. This is the amount one curve must be shifted to obtain coincidence.

These relationships can be used to tie the adjusted delay-time curve between shot points, or to bridge gaps in zones where overlap of the migrated delay-time curves is inadequate or absent.

EXAMPLES

Where mudstone lenses are present in the Shinarump the traveltime curves may have the appearance of standard three-layer plots. A typical series of traveltime curves and two possible interpretations of the data are shown in Figure 5. The first interpretation assumes spreads 1 and 3 to be two-layer plots and spread 2 to be a three-layer plot. Standard two- and three-layer computations were made using the critical-distance method. The second interpretation assumes that the intermediate velocity of spread 2 is caused by refraction from a thin mudstone lens within the Shinarump. The depth computations were made by extending the V_1 part of spread 2 to intersect the V_3 portion of the traveltime curves and treating the problem as a two-layer case, ignoring the V_2 part altogether. The second interpretation fits the local geologic conditions much better than does the first interpretation.

Some error is involved in ignoring mudstone lenses. However, if we assume

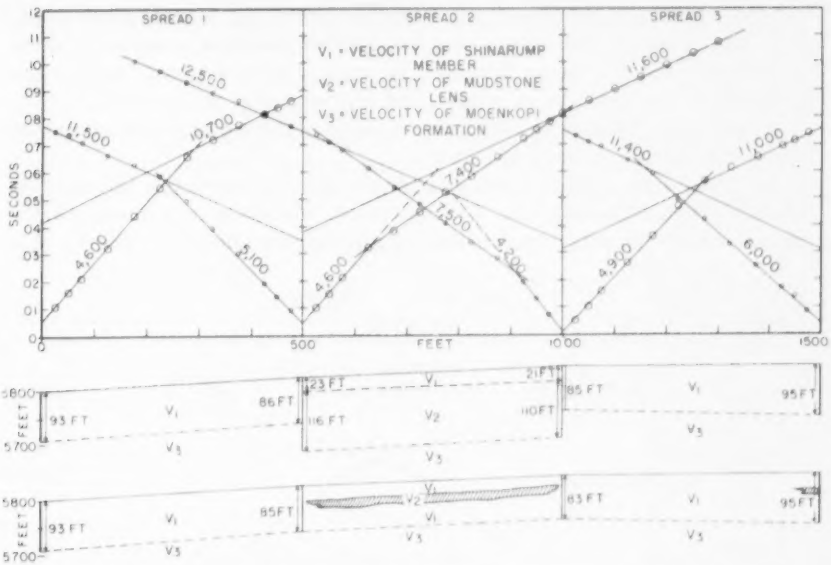


FIG. 5. Graphical illustration of possible misinterpretation caused by mudstone lens.

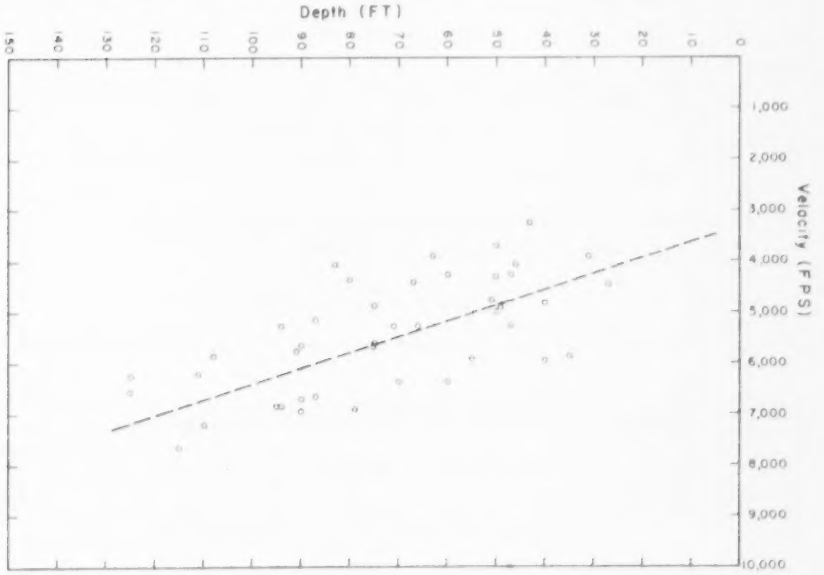


FIG. 6. Inhole velocity measurements in the Shinarump from selected drill holes in a typical Monument Valley area.

that the velocities of the Shinarump, mudstone lenses, and Moenkopi are 4,000, 7,000, and 12,000 fps respectively, and that ignored mudstone lenses account for 25 percent of the Shinarump thickness, the error in the computed depth to the Moenkopi will be less than 10 percent, and relative depths will be accurate.

Actual inhole velocity measurements made in drill holes in the Shinarump of Monument Valley are shown in Figure 6.

The delay-time method of analysis offers a means of extracting the most information from the seismic data. In many places, where a seismic spread spans a channel width, the delay-time method of analysis will show the presence of a

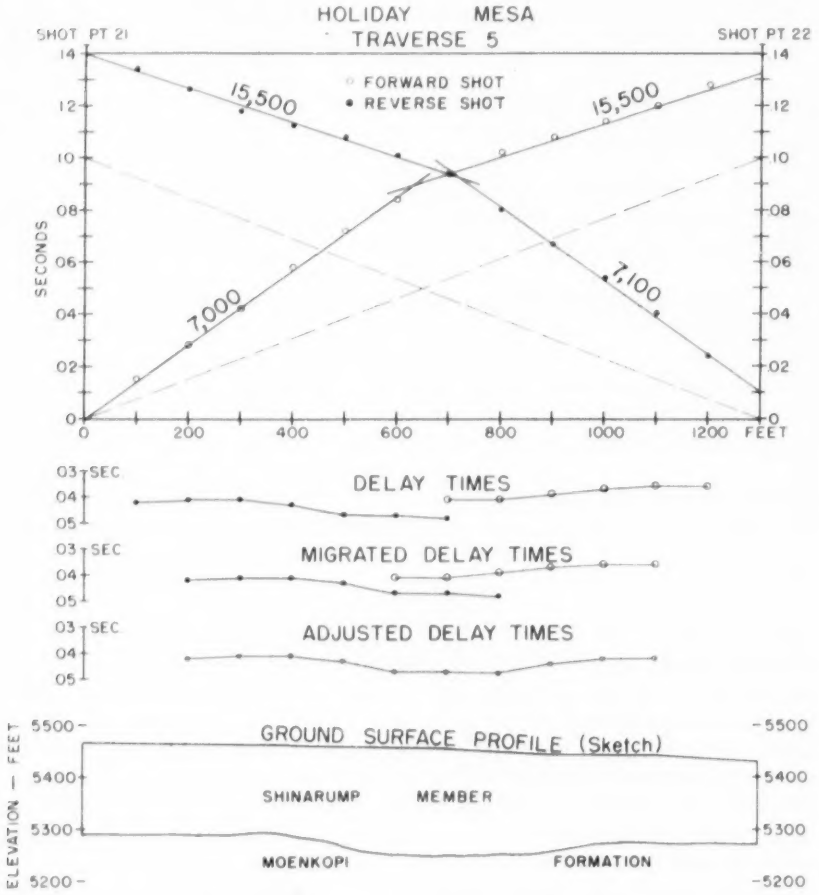


FIG. 7. Channel revealed by delay time analysis.

channel that would remain undetected by standard computation methods. Figure 7 illustrates this situation. Here the traveltime curves appear to indicate that the Shinarump and Moenkopi contact is relatively flat. In reality this spread crosses a channel, although not in a direction normal to the channel axis. The velocities of 15,500 fps as shown on the traveltime curves are apparent velocities indicating upslope travel along the refractor immediately below the V_2 segment for each shot point. This slope reversal reveals the presence of the channel and

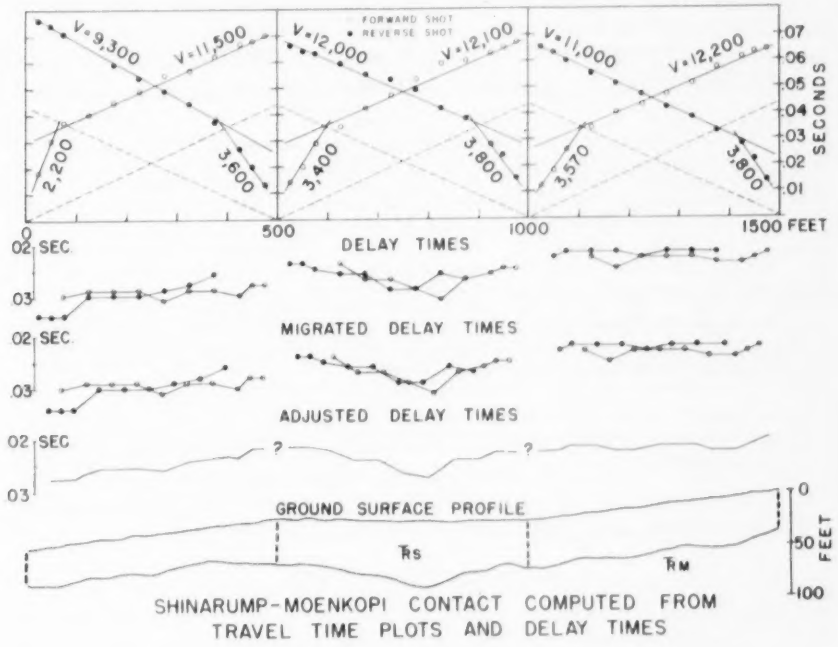
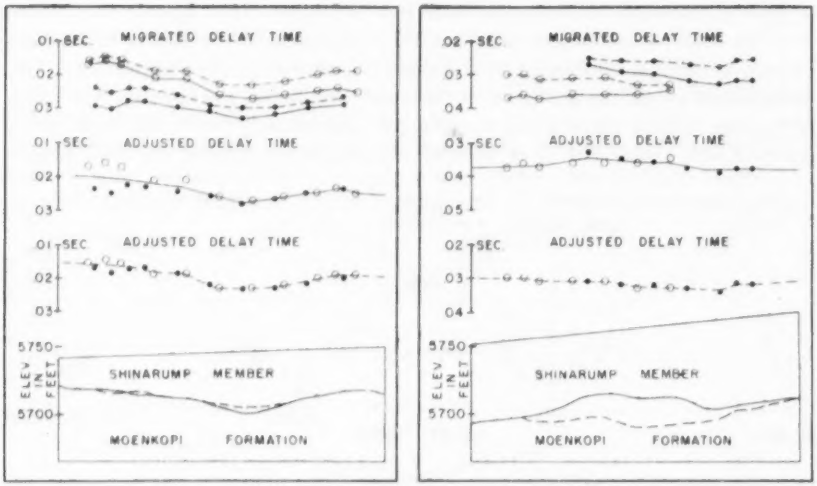


FIG. 8. Typical delay time interpretation.

it is readily detected by the delay-time analysis using a Moenkopi velocity of 13,000 fps.

In some places the presence of a buried channel is indicated on the traveltime curves, even without the use of delay times. In Figure 8 the traveltime curves for the center spread show definite evidence of channeling, which is borne out by the delay-time analysis. The assumed Moenkopi velocity of 12,000 fps is apparently in error for the spread to the left. Depths computed at each shot point by the classical formulas were used here for control.

Where complete overlap is obtained, it may be possible to tolerate fairly large errors in the assumed V_2 by averaging the delay-time curves from opposite direc-



FIGS. 9a and 9b. Effects of erroneous velocities in the Moenkopi. (Solid lines show delay times obtained from erroneous velocities in the Moenkopi; dashed lines delay times for corrected velocities. Conventions for forward and reverse shots same as fig. 8.)

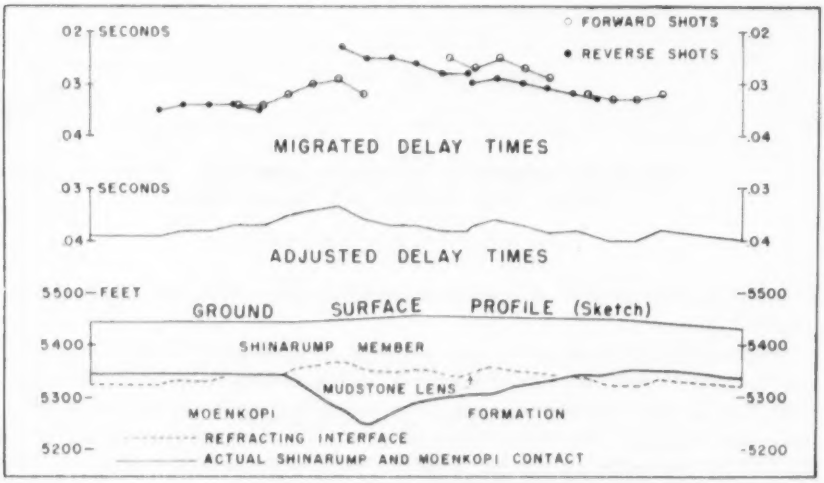


FIG. 10. Effect of mudstone lens in channel on delay time interpretation.

tions, just as it is permissible to average apparent updip and downdip velocities for a dipping bed where the dip is not too great. This procedure can lead to serious discrepancies, however, where the assumed velocity is greatly in error, or if the process is extended too far from one pair of overlapping delay-time curves to the next, and it is not recommended. In Figure 9a the assumed Moenkopi velocity was in error and the migrated delay-time curves were not parallel (solid lines). When the velocity was corrected the migrated delay-time curves became parallel (dashed lines). There is virtually no difference in the adjusted delay-time curves, however. But in Figure 9b the adjusted delay-time curves for the assumed and corrected velocities differ markedly. The correct adjusted delay-time curve (dashed line) indicates the presence of a small channel that might otherwise be overlooked.

The seismic refraction method will not reveal the presence of all buried channels. In some places mudstone will nearly fill the channel scour and, as shown in Figure 10, the top of the mudstone will be mapped instead of the bottom of the channel scour. Parallel profiles where mudstone is missing will reveal the channel.

CONCLUSIONS

The refraction seismograph is a useful tool in the discovery of ancient channels in the Monument Valley area of Arizona and Utah. These channels, cut into the Moenkopi formation by stream action and filled with the basal sediments of the Shinarump, may localize important accumulations of uranium ore in the Shinarump. Exploratory drilling in channels discovered with the refraction seismograph must be relied upon, of course, actually to find uranium ore. The seismic refraction method, using portable jeep-mounted instruments (which can be readily removed for operations in inaccessible areas), is cheap and reliable. It is at present the most successful geophysical method of locating channels used by the U. S. Geological Survey.

Many difficulties in interpretation not anticipated in routine seismic refraction operations are found in exploring for ancient channels, but these difficulties can be overcome by imaginative use of the methods outlined in this paper.

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GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 48-61, 4 FIGS.

REGIONAL GRAVITY SURVEY OF PARTS OF TOOELE, JUAB, AND MILLARD COUNTIES, UTAH*

J. BURLIN JOHNSON, JR.,† AND KENNETH L. COOK‡

ABSTRACT

In the summer of 1955 a regional gravity survey was made in parts of Tooele, Juab, and Millard Counties, Utah. A total of 455 gravity stations were occupied in an area of about 1,700 square miles. A Bouguer anomaly map was compiled with a contour interval of 2 milligals.

Steep gravity gradients indicate major Basin and Range fault zones along the eastern margin of the Cedar Mountains, the southwestern margin of Davis Mountain and its associated outcrops, the northeastern margins of Camels Back Ridge and Simpson Buttes, the eastern margin of Granite Mountain, and the northern margin of the Dugway Range. The principal trend of these fault zones is northwesterly; and they were instrumental in partly outlining several of the mountain ranges in the surveyed area. Great graben with probable vertical displacements of at least several thousand feet were found east of Granite Mountain and northeast of Camels Back Ridge. The highest gravity values, which lie just northwest of Granite Mountain, are about 40 milligals higher than the surrounding surveyed region. Gravity anomalies transecting the Dugway and Thomas Ranges probably indicate pre-Basin and Range faulting.

INTRODUCTION

During June to September 1955, a regional gravity survey was made in parts of Tooele, Juab, and Millard Counties, Utah (Fig. 1). The surveyed area lies in west central Utah between latitudes 39° 30′ N. and 40° 30′ N., and between longitudes 112° 37.5′ W. and 113° 22.5′ W. The surveyed area comprises parts of two northward-trending mountain belts. On the west, from north to south, are Granite Mountain, the Dugway Range, the Thomas Range, the Drum Mountains, and the Little Drum Mountains (Fig. 2). On the east, from north to south, are the southern end of the Cedar Mountains, Davis Mountain, and the Simpson Mountains. Between these two mountain belts is a northward-trending group of subsidiary mountains and ridges which, from north to south, are designated Wig Mountain, Camels Back Ridge, Simpson Buttes, and McDowell Mountain.

The regional gravity survey was made to determine, insofar as possible, the regional structure and lithology of the underlying rocks. In particular, it was hoped that the gravity survey would help outline some of the geologic trends and give useful information in regard to mineral deposits and ground water.

FIELD TECHNIQUES AND REDUCTION OF DATA

A Worden gravimeter with a sensitivity of 0.0995 milligal per dial division was used throughout the survey. A total of 455 gravity stations were taken within

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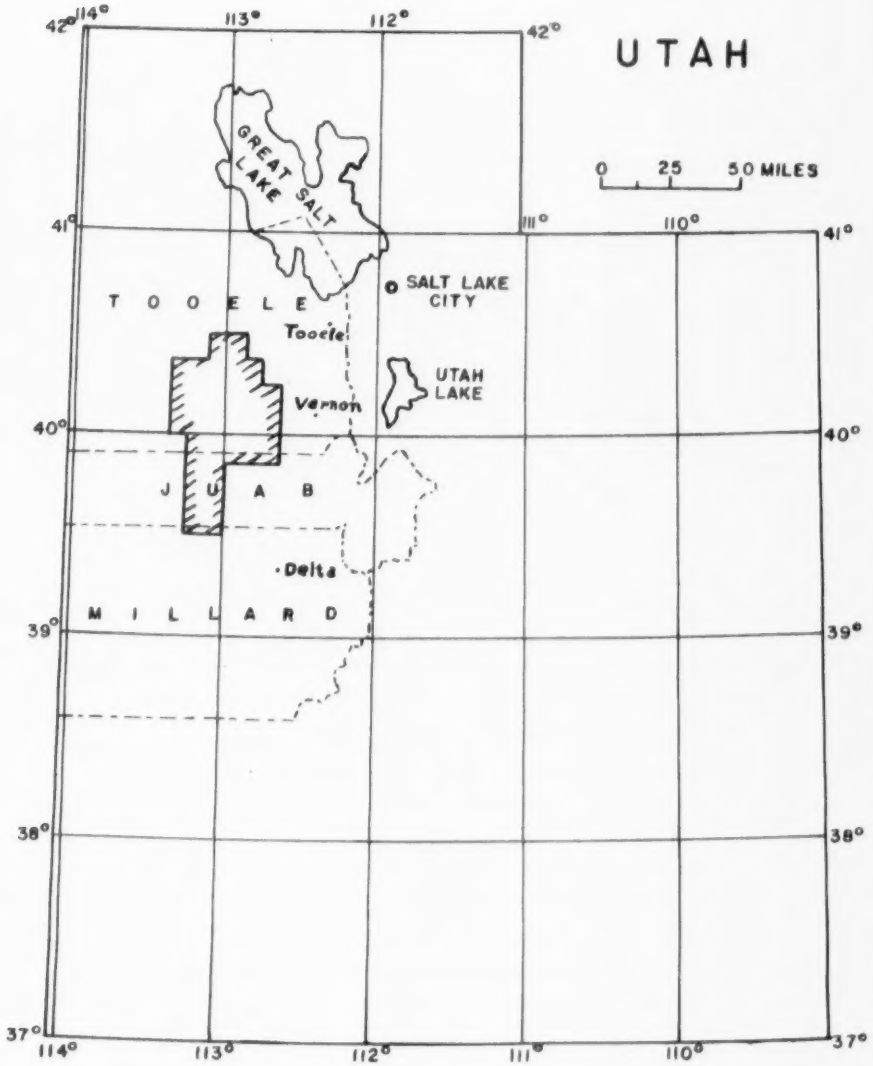
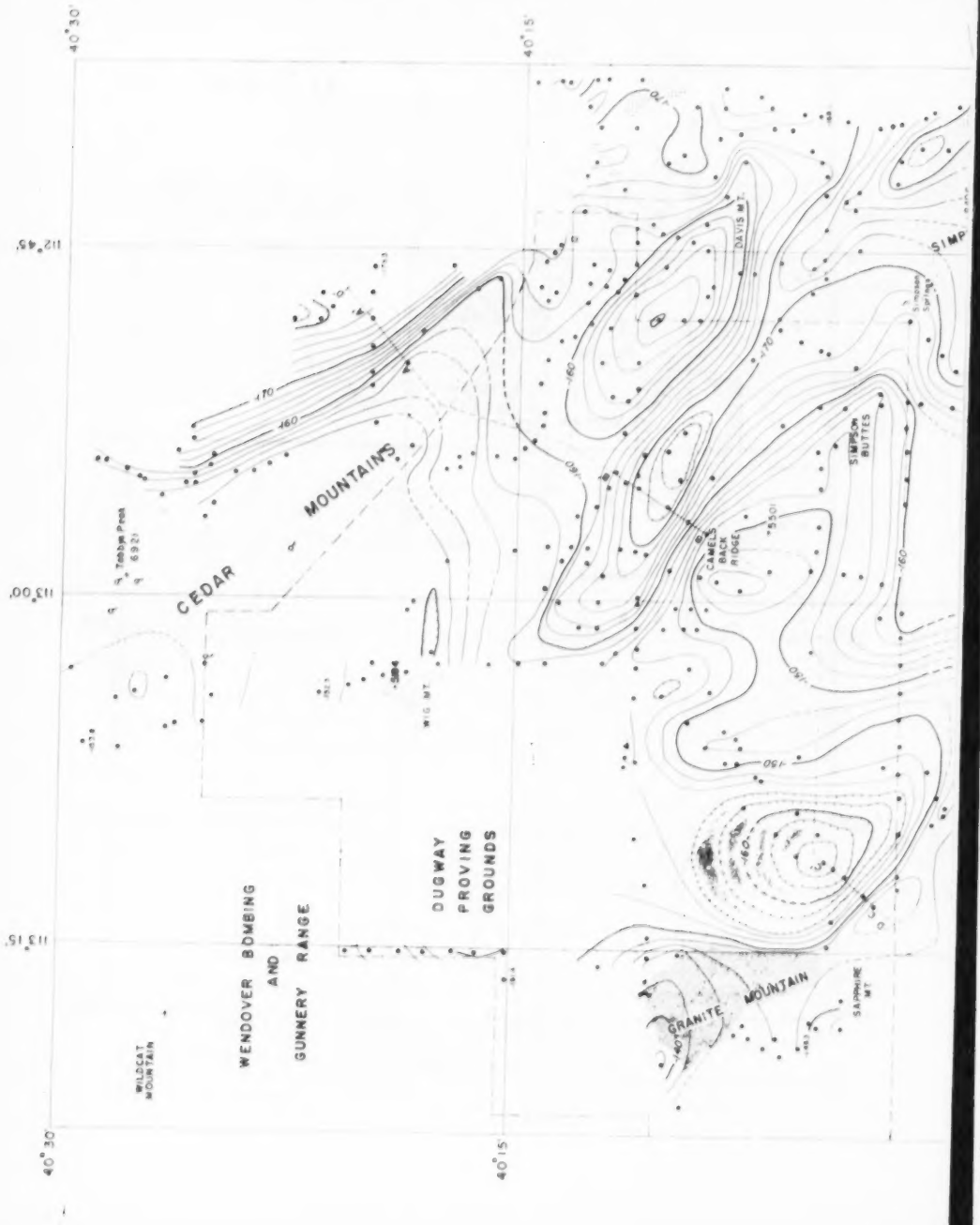


FIG. 1. Area covered by gravity survey.


40°30'
40°15'
112°45'
113°00'
113°15'
CEDAR MOUNTAINS
Topaz Peak
6921
DAVIS MT.
SIMP
SIMPSON BUTTES
CAMEL BACK RIDGE
6540
5501
DUGWAY PROVING GROUNDS
WENDOVER BOMBING AND GUNNERY RANGE
WILDCAT MOUNTAIN
GRANITE MOUNTAIN
SAPPHIRE MT.
6073
470
460
450
440
430
420
410
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
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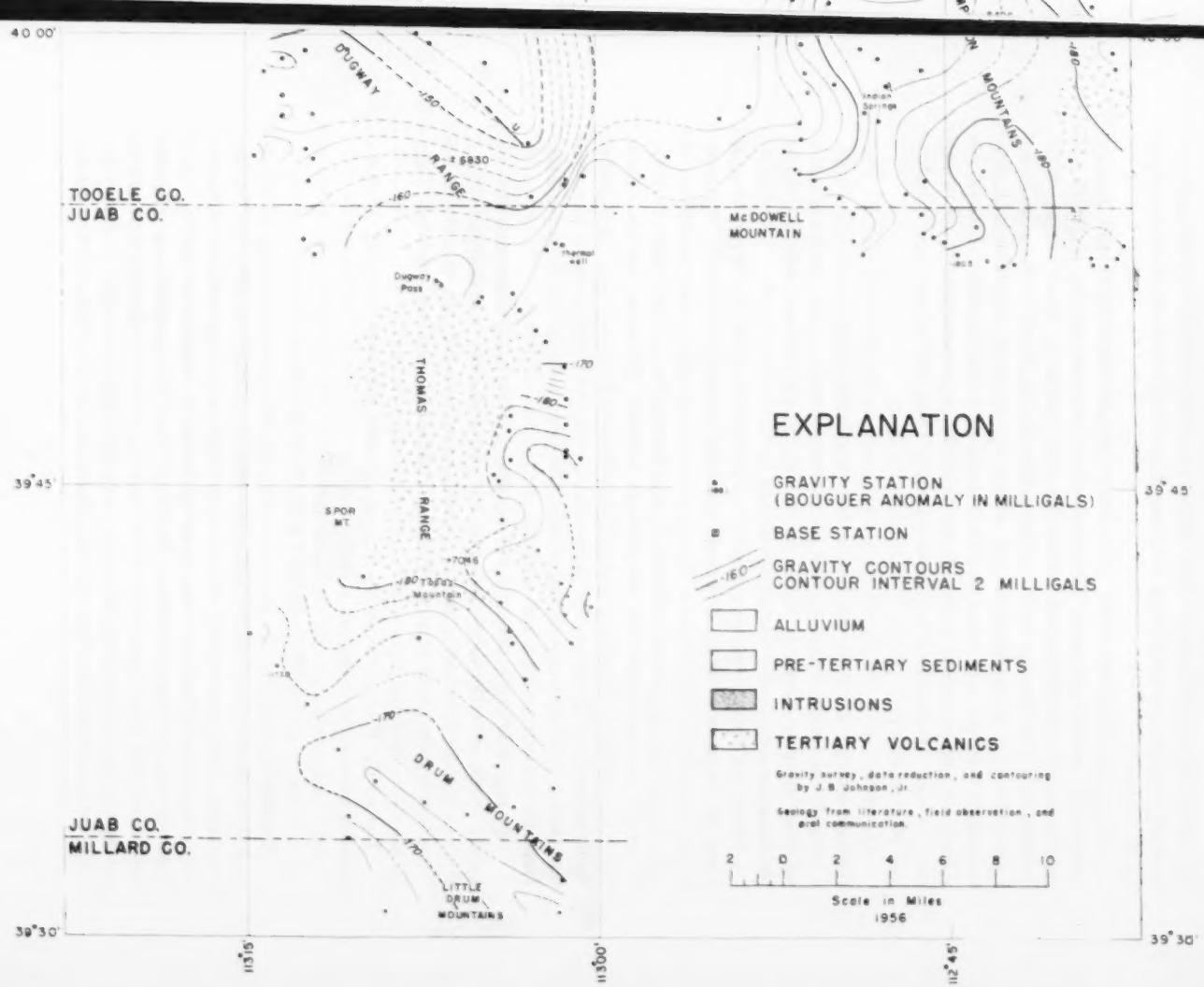


FIG. 2. Bouguer gravity map of parts of Tooele, Juab, and Millard Counties, Utah.

an area of about 1,700 square miles. The precision of the field measurements is believed to be within 0.2 milligal for most of the stations and within 0.5 milligal for all stations.

All station elevations were taken from United States Geological Survey topographic quadrangle maps. The station locations and spacing therefore depended on the distribution of known elevation points at bench marks, road intersections, and other useful elevation points. Essentially all of these points of known elevation accessible to a jeep within the surveyed area were occupied as gravity stations. The elevations were probably correct within a foot in the valleys and within about 4 feet in the foothills and mountains. Most of the stations were taken in the valley and foothill areas due to the inaccessibility and poor topographic control in the mountain areas.

The reduction of the gravity data was carried out in the usual manner. The readings were corrected for instrument drift; and latitude corrections were made. The observed gravity values for the stations were corrected to a datum of mean sea level using an elevation correction of 0.06 milligal per foot, which includes the Bouguer correction for a density of 2.67.

No terrain corrections were applied to the data because they were insignificant in comparison with the size of the chief anomalies found in the area. Using Hammer's (1939) charts, sample terrain corrections were carried out to and including zone J at 18 selected stations having some of the largest terrain corrections in and around the mountains of the area. The largest terrain correction was 2.1 milligals; and only 4 of the 18 stations had terrain corrections greater than one milligal. Checks in the valleys showed that the terrain corrections were less than 0.1 milligal about 4 miles from the mountains in the surveyed area. Isostatic corrections were not made.

The simple Bouquer anomaly values, shown in Figure 3, were computed by taking as reference the simple Bouquer anomaly value of −183 milligals for the U. S. Coast and Geodetic Survey pendulum station No. 49, located in the Temple Grounds in Salt Lake City and established in 1894 (see Duerksen, 1949, p. 8).

The simple Bouguer anomaly map of the area is shown in Figure 2, with a contour interval of 2 milligals.

REGIONAL GRAVITY AND REGIONAL GEOLOGY

The area covered by the gravity survey is in the Basin and Range province, and about 70 miles west of the Wasatch Mountains, which lie along the eastern boundary of the province. The faults of the Basin and Range orogeny are superimposed on earlier Laramide and possibly Nevadan structures (Eardley, 1951, Fig. 280) in the region surveyed. The largest gravity anomalies are generally associated with Basin and Range block faulting, where the density contrasts in places are high; however, the gravity manifestations of earlier orogenies are also present where the older structures have resulted in subjacent rock masses

of strong density contrast. The relief of the bedrock mountains is probably due partly to pre-block-faulting relief and partly to later Basin and Range faulting (Eardley, 1933).

Very little regional geology has been done in the area surveyed; most of the geologic work has been confined to local mining prospects. Butler (1920) described briefly some of the salient structural features and trends of parts of the area. The Dugway Range, Simpson Mountains, Cedar Mountains, Drum Mountains, Camels Back Ridge, and Simpson Buttes consist mainly of Paleozoic sediments. Granite Mountain is a large intrusive, and the Thomas Range is covered by Tertiary volcanics. The area between the mountain ranges is covered with valley fill, which obscures the regional structural features.

Cedar Mountains Area

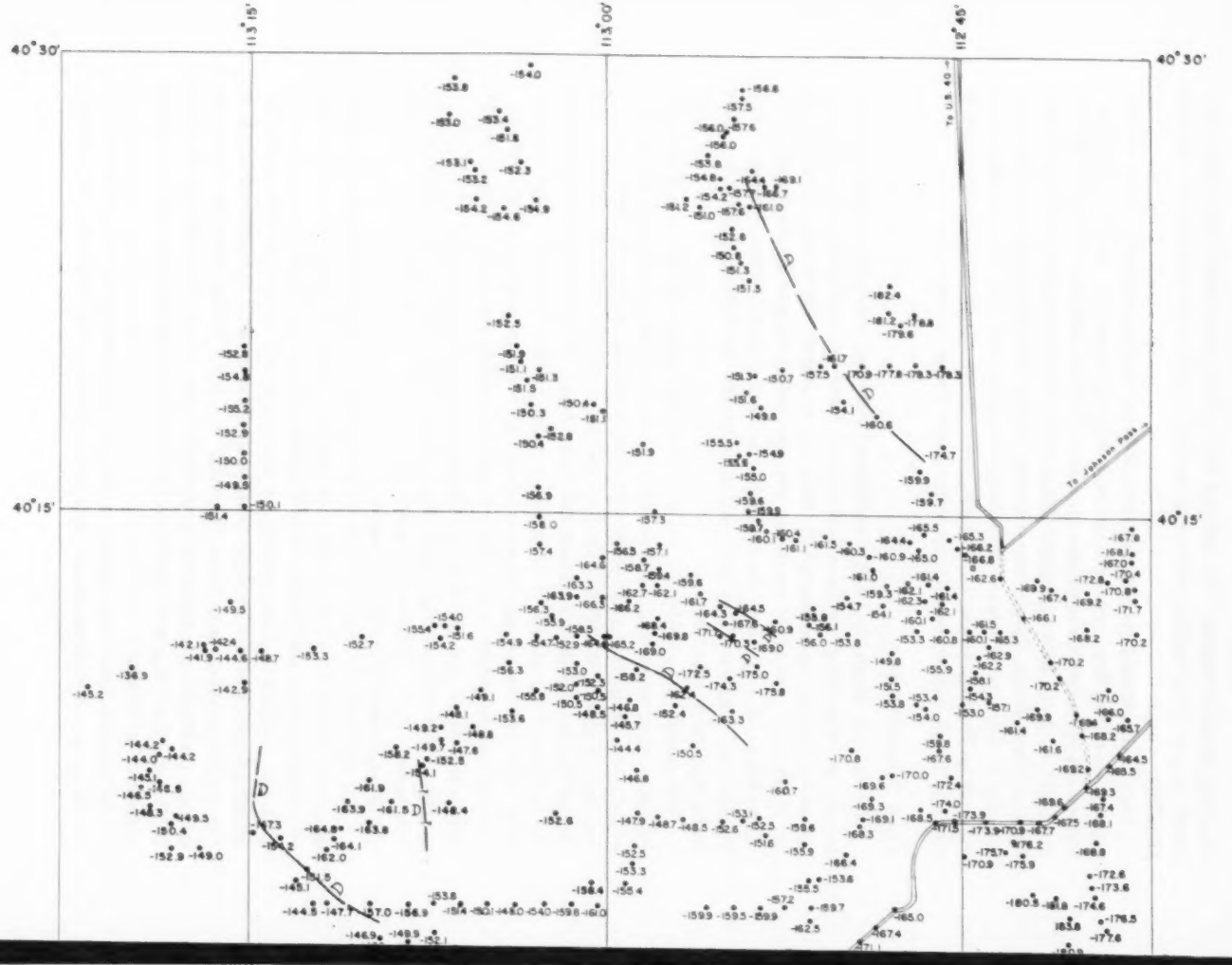
The Cedar Mountains are a northward-trending mountain range approximately 40 miles long, composed mainly of Paleozoic sediments and Tertiary volcanics (Butler, 1920, Plate IV). Only the southern end of the range, which bends abruptly toward the southeast, was covered in the gravity survey. According to King (1876, p. 462), the southern end of the range consists mainly of red iron-stained quartzites and limy shales, upturned at varying angles, but generally dipping north or east.

The gravity data indicate a major north-northwestward-trending Basin and Range fault zone along the eastern margin of the Cedar Mountains in the surveyed area. Here the north-northwestward-trending gravity contours show a decrease of about 30 milligals over a horizontal distance of about 4 miles. Although the data in the area where the Cedar Range bends northward are sparse, the bending of the gravity contours here indicates that the fault zone also probably bends northward and extends along the eastward margin of the range.

Theoretical profile A-A′ (Figs. 2 and 4), which was taken in a direction perpendicular to the trend of this anomaly, fits approximately the observed gravity curve when a single fault dipping 50° N.E. with a throw of 6,750 feet is assumed. A two-dimensional graticule was used to compute this profile and the other profiles shown in this paper.

For this and the other profiles in this paper, a density contrast of 0.4 was assumed to exist between the bedrock and the valley fill. This choice was based on values given in the Handbook of Physical Constants (Birch, 1942), assuming that the bedrock consists mostly of limestone and quartzite with a density about 2.6 and that the average density of alluvium and Tertiary sediments in the valleys is about 2.2. Since the value 0.4 is probably near the maximum density contrast to be expected, especially for the deeper alluvium and Tertiary sediments, the computed depths of the alluvium and Tertiary rocks probably represent a minimum.

Although a single master fault is shown, the same gravity effect can be produced by a series of parallel or sub-parallel faults close together. The gravity


40°30'
40°15'
40°00'
113°15'
113°00'
112°45'
To U.S. 40
To Johnson Pass

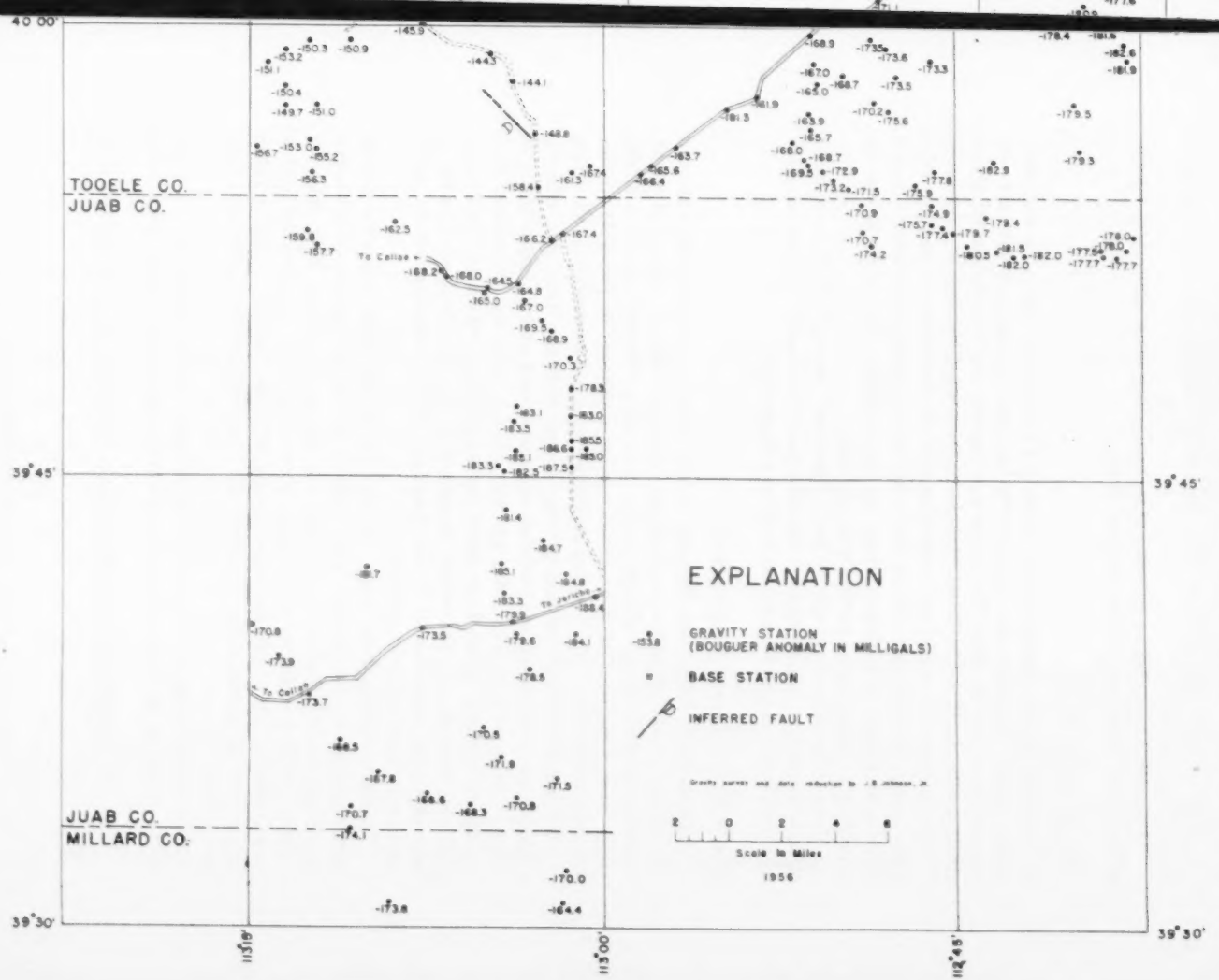


FIG. 3. Simple Bouguer anomaly values in parts of Tooele, Juab, and Millard Counties, Utah.

map (Fig. 2) shows that the fault zone must either terminate or swing eastward toward the southeast.

The gravity data give no evidence of faulting along the southwestern margin of the Cedar Mountains in the surveyed area.

Davis Mountain Area

Davis Mountain consists mostly of early Paleozoic (?) quartzites and limestones. Davis Mountain and the scattered outcrops to the northwest are well outlined by a gravity high. Pre-Tertiary sediments crop out in several places about 5 miles northeast of Davis Mountain; and a small outcrop of Cretaceous (?) conglomerate occurs about 2 miles east of the mountain. A small gravity scarp along the northeast side of Davis Mountain possibly indicates a minor Basin and Range fault down-thrown on the northeast; but it could also be caused by a bedrock slope covered with alluvium.

Along the southwestern side of Davis Mountain and associated outcrops to the northwest,[1] the northwestward-trending gravity anomaly with a steep gradient is probably caused by a major Basin and Range fault.

Camels Back Ridge and Simpson Buttes

Camels Back Ridge and Simpson Buttes, which both consist of Paleozoic (?) sediments, are separated from Davis Mountain and its associated northwesterly outcrops by an alluvial valley. The only outcrops observed in this valley were some rhyolite flows about 2 miles southwest of Davis Mountain. No holes deeper than about 200 feet are known to have been drilled in this valley.

The northwestward-trending gravity trough indicates that the valley is probably an elongate graben trending northwestward and having a throw of several thousand feet. The steep gravity gradient northeast of Camels Back Ridge and Simpson Buttes is probably the manifestation of a Basin and Range fault that forms in part the western margin of the graben. The Basin and Range fault extending northwest of Davis Mountain, already discussed above, forms the eastern margin of the graben.

Theoretical profile B-B′ (Figs. 2 and 4), which was taken across the graben, gave a good fit for the geologic section shown and an assumed density contrast of 0.4 between the bedrock and valley fill. Along this section B-B′ only, the regional gradient was removed from the observed gravity to obtain the residual gravity profile, which corresponds so closely with the theoretical gravity profile for the geologic section shown that only one curve is drawn in Figure 4 for these two profiles.

The gravity nose in the vicinity of Simpson Buttes, including the broad flanks extending on either side both northwestward toward Camels Back Ridge

[1] Not all of the small outcrops in this area could be shown on the map at the scale used in this paper.

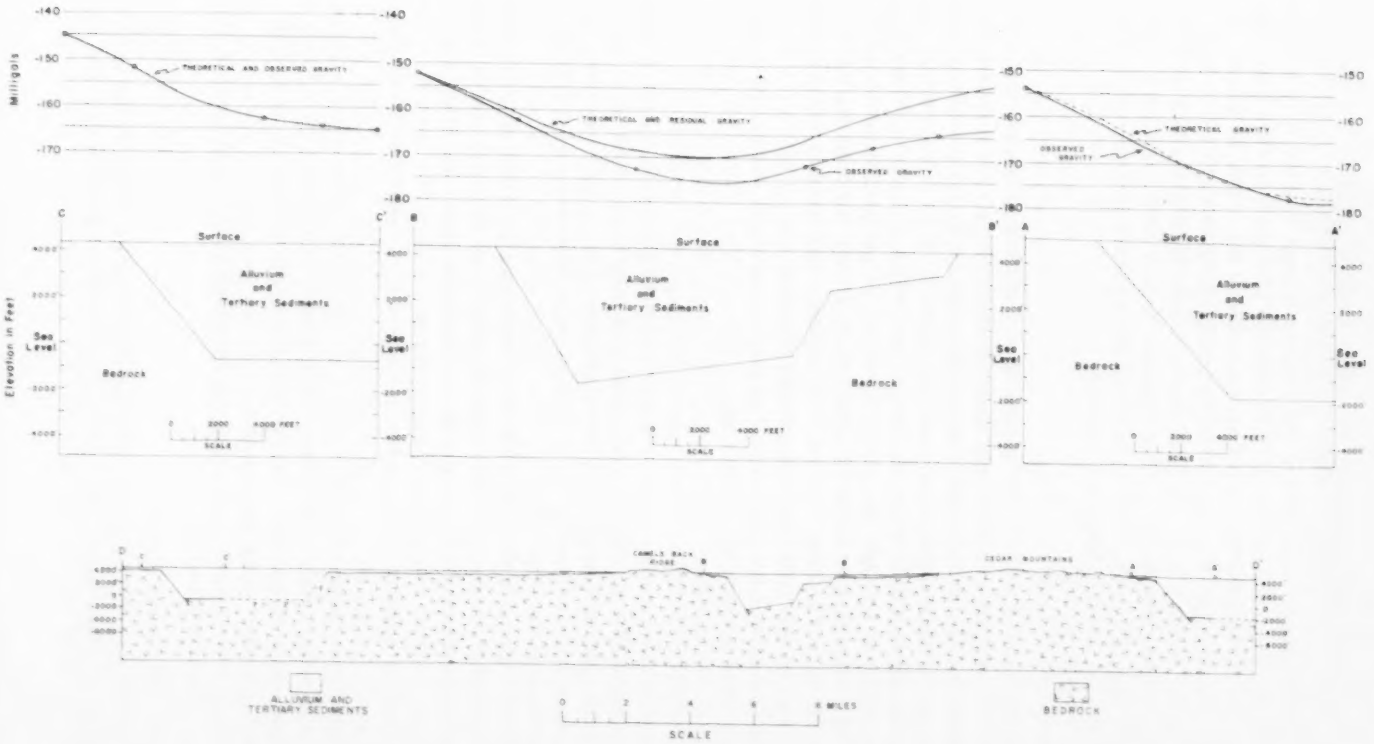


FIG. 4. Interpretative geologic profiles and theoretical profiles (assumed density contrast for all profiles is 0.4).

and westward for 10 miles toward the Dugway Range, is difficult to explain solely by Basin and Range faulting. The contours with small gradient overlying the outcrops at Simpson Buttes suggest that some of this V-shaped anomaly is associated with a structural feature that antedates the Basin and Range orogeny. If any of the anomaly in the Simpson Buttes-Camels Back Ridge area is due in part to pre-Basin and Range faulting, a smaller density contrast than 0.4 would probably exist; and the actual throw would consequently be greater than that indicated in the geologic section in Figure 4.

Simpson Mountains Area

The Simpson Mountains are composed of Cambrian sediments consisting mainly of quartzite, limestone, and shale (Butler, 1920, p. 446–448) and Precambrian rock (R. E. Cohenour, oral communication). At the northern end of the range, the rocks strike easterly and dip northerly. Near Indian Springs and at the southern end of the range, they strike northwest and dip 30°–35° northeast (Butler, 1920, p. 448–449). The Simpson Mountains are part of the Sheeprock uplift of the Laramide orogeny (Eardley, 1940, p. 823), and were the site of a trough in early Cambrian and late Precambrian time because sediments in excess of 11,500 feet thick accumulated there (Eardley, 1940, p. 831).

The regional gravity apparently does not correlate with the known surface geology in the Simpson Mountains area.

Granite Mountain Area

Granite Mountain is composed of granite cut by pegmatite and basic dikes of later age whose strike corresponds with the general northerly trend of the range. Outcrops of quartzite and schist (Butler, 1920, p. 460) known as Sapphire Mountain lie immediately south of Granite Mountain and northwest of the north tip of the Dugway Range.

The gravity low with a closure of about 8 milligals lying just east of Granite Mountain indicates that a graben probably exists here. The steep gravity gradient extending along the eastern margin of Granite Mountain and southeastward along the northern margin of the Dugway Range indicates that the western and southwestern margins of the graben are formed by a major Basin and Range fault zone.

Theoretical profile C-C′ (Figs. 2 and 4), which was taken across this fault zone at a point where the gradient is most pronounced, gives a good fit for an assumed single master fault dipping 50° N.E. with a throw of 5,000 feet. A density constrast of 0.4 was assumed.

No gravity evidence of faulting was found along the northern or western sides of Granite Mountain.

Dugway and Thomas Ranges

The Dugway Range is separated from the Thomas Range to the south by Dugway Pass. The Dugway Range consists mainly of Cambrian quartzite, lime-

stone, and shale, although Ordovician rocks are also present (M. H. Staatz, oral communication). The rocks exposed in the Thomas Range are mostly rhyolitic and other volcanic flows and tuffs. Spor Mountain, lying west of the southern part of the Thomas Range, is composed of Paleozoic sediments.

The northerly trending gravity contours with a steep gradient east of the Dugway Range swing abruptly westward and transect the range just north of the Tooele County line and about 4 miles north of Dugway Pass. The fact that these contours cut across the prevailing northerly strike of the westward-dipping beds in this part of the range indicated that a major fault transverse to the range probably placed rocks of different densities against each other at or beneath the surface. On the basis of the gravity anomaly, a major fault was hunted for, and found in this area. The fault strikes northwest along the eastern side of the range, about 3 miles north of the Tooele County line. The fault placed quartzite on the north against younger limestone on the south. If this fault dips to the south, its location is approximately correct for explaining the observed anomaly; but a paradoxical relationship regarding the relative densities exists because limestone is normally at least as dense as quartzite, and in this case gravity decreases toward the south. Thus if the observed anomaly is caused by the observed fault, it must be because denser rock beneath the quartzite has been faulted nearer the surface. Detailed geologic work in the area is necessary to decipher this problem. The fault trace is approximately parallel to both the gravity contours in the immediate area of the fault and also the strike of the major fault along the northern margin of the Dugway Range.

Two miles east of the Thomas Range, the steep gravity gradient trending in a direction transverse to the Thomas Range indicates that a major break probably exists transverse to the range. Because there is apparently no evidence of a major break in the volcanics, which cover essentially all of this area (M. H. Staatz, oral communication), the inferred fault is probably Laramide or older in age. A volcanic plug in the Thomas Range due west of the observed anomaly (M. H. Staatz, oral communication) may be associated with the inferred break.

Drum Mountains Area

The Drum Mountains and Little Drum Mountains comprise mainly Cambrian quartzites, shales, limestones, and some extrusives (Butler, 1920, p. 459–464). The area contains several abandoned and several producing metalliferous mines; the ore occurs in the sedimentary rocks. The eastward-trending gravity contours in the area between the Thomas Range and Drum Mountains reveal a 10-milligal gradient over a horizontal distance of about 5 miles.

Regional Considerations

The regional gravity survey reveals several major patterns in the surveyed area. The highest gravity values center over an area just northwest of Granite Mountain. The gravity values in the surveyed area decrease in all directions

away from this high: about 40 milligals toward the Thomas Range to the south; about 40 milligals toward the Simpson Mountains to the southeast; and about 20 milligals toward the Cedar Mountains to the northeast. It is not known whether this large gravity relief is due to a major structural feature or to density contrasts within the basement complex.

The striking northwestward trend of the gravity contours with steep gradients indicate that the principal breaking of the earth's crust in this region due to Basin and Range faulting occurred along a northwestward-trending pattern. Movement along these major Basin and Range fault zones has been instrumental in partly outlining several of the mountain ranges in the surveyed area.

The eastward-trending gravity contours in places reveal major structural features that probably are a manifestation of orogenic movement prior to Basin and Range faulting.

The interpretive geologic section D-D′ extending northeasterly across the area is shown on Figure 4. No theoretical profile was computed for the inferred fault lying along the eastern margin of the graben east of Granite Mountain; the dip and throw of this fault were estimated qualitatively from the observed gravity gradient and from the fault lying to the southwest shown in section C-C′.

SUMMARY AND CONCLUSIONS

The regional gravity survey reveals pronounced anomalies that are believed caused chiefly by Basin and Range faulting and partly by earlier orogenies. Steep gravity gradients of about 10 milligals per mile indicate major Basin and Range faults along the eastern margin of the Cedar Mountains, the southwestern margin of Davis Mountain and its associated outcrops, the northeastern margins of Camels Back Ridge and Simpson Buttes, the eastern margin of Granite Mountain, and the northern margin of the Dugway Range. Great graben with probable vertical displacements of at least several thousand feet were found; one lies east of Granite Mountain, and the other lies northeast of Camels Back Ridge.

The striking northwestward trend of the gravity contours with steep gradients indicate that the principal breaking of the earth's crust in this region due to Basin and Range faulting occurred along a northwestward-trending pattern. Movement along these major Basin and Range faults has been instrumental in partly outlining several of the mountain ranges in the surveyed area.

There is gravity evidence of pre-Basin and Range faulting in the Dugway and Thomas Ranges, where two major east-west gravity trends transect the northward trend of the mountains. There is geologic evidence for a major fault in the Dugway Range.

The highest gravity values center over an area just northwest of Granite Mountain. The gravity values in the surveyed area decrease in all directions away from this high. It is not known whether this large gravity relief is due to a major structural feature or to density contrasts within the basement complex.

ACKNOWLEDGMENTS

Acknowledgment is made to the Bear Creek Mining Company for financing the field work. Appreciation is expressed to Professor A. J. Eardley, Dean of the College of Mines and Mineral Industries, University of Utah, for helpful suggestions; and to R. E. Cohenour, graduate student at the University of Utah, and M. H. Staatz of the United States Geological Survey, for the information they furnished on the regional geology of the area. We also thank Colonel D. D. Bode, Commanding Officer, Dugway Proving Ground, for his permission to work on the military reservation.

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GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 62-66, 3 FIGS.

A GRAVITY MAXIMUM IN THE GREAT VALLEY OF CALIFORNIA DUE TO THE ISOSTATIC EFFECT OF THE SIERRA NEVADA*

L. F. IVANHOE†

ABSTRACT

A gravity maximum extends along the full length of the Great Valley of California. This feature is believed to represent the western limit of the gravity effect due to the adjustment of the Sierra Nevada isostatic block. Recognition that such a maximum with a sedimentary basin may be due to isostasy rather than to shallow geologic features assists in the interpretation of gravity data.

A large Bouguer gravity minimum exists along the granite Sierra Nevada range, as would be expected from high mountains in isostatic adjustment. Another extensive gravity minimum is located along the west side of the Great Valley of California where the sedimentary rocks are thickest. A broad gravity maximum "ridge" lies between these two minima. This maximum is parallel to and about 80 miles west of the crest and 20 miles west of the basement outcrop of the Sierra Nevada. These features are so large that their relationship only becomes apparent on a regional gravity map.

The known details of the geology limit theories regarding the reason for the maximum. The many oil wells drilled in the area show the structure to be essentially a westerly dipping homocline from the basement outcrop on the stable (east) side of the basin to the deep syncline on the west side of the Great Valley. The west and south sides of the San Joaquin Valley are along the mobile sides of the basin where the mountains are due to large thrusts faults. The principal structures of the Coast Ranges are the major NW-SE trending faults which are subparallel to the San Andreas fault.

Detailed gravity surveys show that the trend of the main maximum "ridge" is commonly obscured by superimposed sharper local anomalies so the relationship of the maximum to the range is not apparent on a map of a small area. Cores from deep wells indicate that at least some of these smaller anomalies are due to local petrographic changes in the basement composition, but these variations do not account for the main maximum ridge. There is no shallow structural reason for this anomaly.

The extent and parallel relationship of the Great Valley gravity maximum to the Sierra Nevada strongly suggests that it is associated in some manner with isostatic adjustment. It appears that the maximum is merely a line of gravity inflection (isostatic hinge line) reflecting the westerly limit of the gravity effect due to the local adjustment of the Sierra Nevada isostatic block. Gravity data over the mountains at the south end of the Great Valley show no such complete

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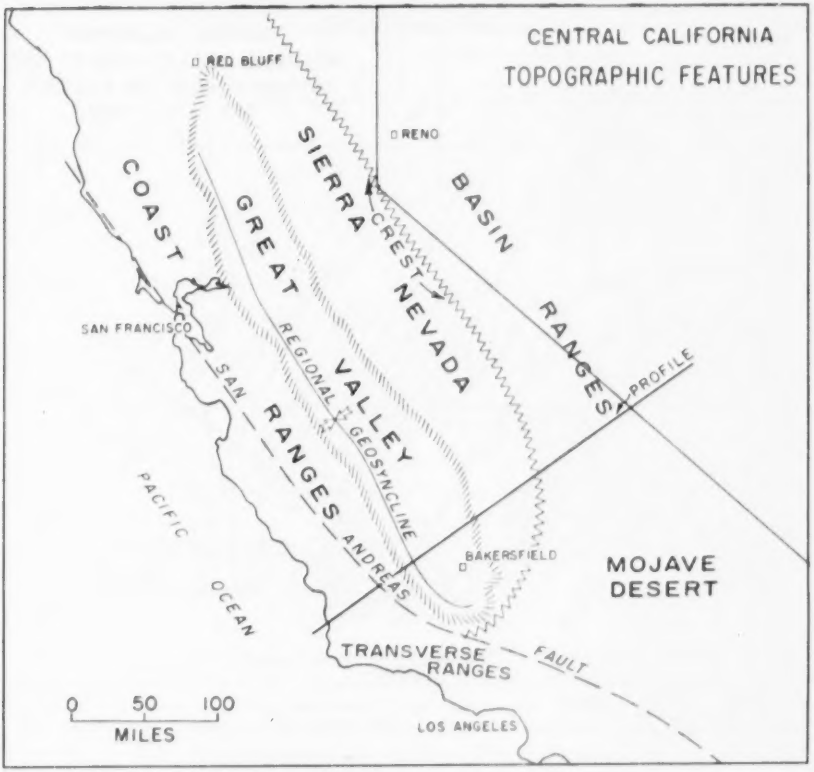

FIG. 1. Central California Topographic Features. Edge of Great Valley alluvium indicated by hachures. Approximate locations of San Andreas fault and Great Valley geosyncline are indicated. The Sierra Nevada is along the stable side of the basin.

isostatic adjustment as over the Sierra Nevada. This indicates that these mountains which have resulted from thrust faulting along the mobile rim of the basin are isostatically separated from the stable Sierra Nevada block. The gravity effect of this contrast is the southerly disappearance of the large Sierra Nevada minimum and also of the Great Valley gravity maximum ridge. This relationship is not apparent from an examination of a topographic map since the southern ranges are 5,000 to 9,000 feet high and appear to be mere extensions of the main Sierra Nevada mountains.

It is proposed that the total mass of the high (9,000′–14,000′) Sierra Nevada mountains is large enough to produce local isostatic balance almost directly under the range as contrasted to broader isostatic adjustments under smaller mountains of less concentrated mass (like the California Coast ranges.) This

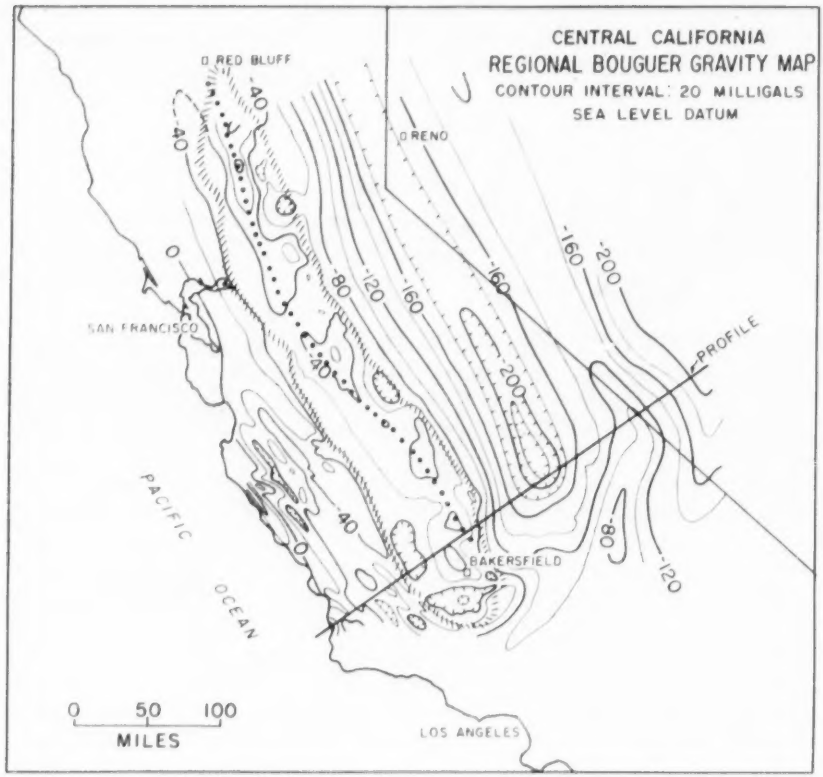

FIG. 2. Central California Regional Bouguer Gravity Map. Contour interval 20 milligals. Edge of Great Valley alluvium indicated by hachures. Great Valley gravity maximum indicated by the line of dots.

may be analogous to the difference in adjustment of ice blocks on top of shaved ice in a pail of water. The wet slush tends to support small chunks of ice up to a certain size, but larger blocks are not supported and adjust individually.

The interpretation of sedimentary and shallow basement structures from gravity data along the Great Valley maximum is abnormally difficult due to its tendency to obscure smaller local anomalies. Estimates of basement depths may be grossly in error within the area of local isostatic adjustment. Residual gravity maps should probably be normally effective within most of the isostatic zone, except along the isostatic "hinge line" itself where a series of positive residual anomalies result which have no shallow structural or petrographic significance and may be very misleading if they are not properly recognized.

Local isostatic gravity maxima may be expected within other basins that are

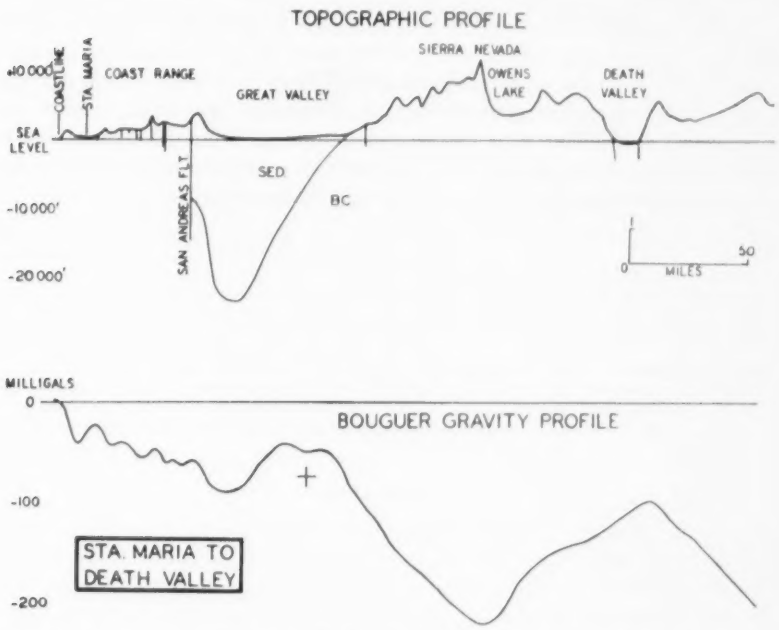

FIG. 3. *Topographic and Bouguer profiles from Santa Maria to Death Valley, California.* The location of the basement complex (BC), Sedimentary basin (Sed) and the San Andreas and some Coast Range faults are indicated. West of the Great Valley maximum (+) there is a moderate regional isostatic gravity slope towards the east with direct correlation of gravity anomalies and sedimentary structures (synclines over gravity minima and vice versa). The westernmost of the two local bumps on this maximum (+) is believed to be due to a local change in the basement composition. The negative gravity effect due to the Sierra Nevada isostatic block is apparently limited by the Great Valley maximum and the maximum at Death Valley.

near high mountain ranges or large batholiths, etc., of great concentrated mass. A comprehensive study of the occurrences and types of isostatic anomalies may refine the theories of isostasy and permit improved interpretation of gravity data. However, it seems unlikely that most such anomalies will be recognized as easily as in California. The topographic relationship of the Sierra Nevada and the Great Valley is unique in the United States and is unusually simple with a long, straight, relatively narrow mountain range of high topographic contrast to the adjoining valley. The geologic structure is, furthermore, most simple with the Sierra Nevada being located on the stable rather than the mobile side of the basin.

Anticipation of the possibility of such "isostatic hinge lines" with their associated gravity anomalies may permit their recognition in other areas and aid in the interpretation of gravity data. Gravity surveys should be suitably planned

to include regional lines over the mountains in areas where a local isostatic anomaly is suspected so the existence of the anomaly can be checked. The particular type of anomaly in any area should depend on details of the local geology. A mere change of gravity gradient may occur in some cases rather than an actual reversal of gradient as is the case in California. Mountain ranges due to thrust faulting on the mobile sides of a basin may produce quite different isostatic anomalies than along the stable side of the same basin.

GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 67-74, 3 FIGS.

CALCULATION OF GUARD ELECTRODE RESPONSE CURVES*

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HERNAN TEJADA-FLORES‡‡

ABSTRACT

In the existing theories of guard electrode logging, the electrode is approximated by a prolate spheroid. All equipotential surfaces are assumed to be concentric prolate spheroids and the current nappes are bounded by hyperboloids. This picture ignores the refraction of current at the boreface and at the boundary of invaded zones of porous formations.

A new approach to guard electrode theory has been formulated in which the electrode is represented by a series of spheres having the same diameter as the electrode. The boreface and invaded zone boundary are considered to be cylindrical. The current from each sphere is calculated from the condition that all spheres must be at the same potential and the potential distribution is found by superposition of the fields due to the individual currents.

For small drill holes in otherwise homogeneous formations of moderate resistivity the prolate spheroid approximation gives results that are identical with those of the present theory. For larger holes, invaded formations and large resistivity contrasts, the prolate spheroid method is shown to give varying degrees of error in the calculated apparent resistivities.

INTRODUCTION

The calibration and interpretation of guard electrode response to date has been based on a theory (Guyod; Owen and Greer) in which the electrode is approximated by a prolate spheroid. The major axis of the prolate spheroid is taken equal to the total electrode length and the minor axis equal to the electrode diameter. For the case of long guards in a homogeneous medium, this approximation gives a fairly accurate picture of the current distribution, particularly if we are interested only in the current from the central electrode. In the prolate spheroid method, all equipotential surfaces are assumed to be concentric prolate spheroids and, therefore, the current nappe from the central electrode is bounded by hyperboloids.

In the practical cases where the surrounding medium is divided into separate parts, having different resistivities, by the boundaries of the drill hole and the invaded zones of porous formations, these boundaries are also approximated by prolate spheroids, concentric with the electrode. Since the boundaries are artificially made to coincide with the equipotential surfaces no current refraction occurs at any of the interfaces. Where the current is essentially perpendicular to the boundary as is the case for the central current at the boreface of small diameter drill holes, this neglecting of the effects of current refraction is quite permissible. However, in large holes and in the case of invaded formations the current will no longer be perpendicular to the boundaries. The degree of current

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refraction will depend upon the particular geometry and upon the resistivity contrasts across the boundaries.

In many considerations involving the current distribution from the guards, the prolate spheroid approach breaks down entirely. This can be easily visualized if we consider a guard electrode in a drill hole where the resistivity of the drilling fluid is much smaller than the formation resistivity. The conductive drill hole will exert a strong shunting effect causing large amounts of current to flow from the end points of the guards into the hole and to enter the formation only at relatively large distances. In the prolate spheroid approximation, the hole is considered to have a spheroidal boundary which is closed at both sides of the guard arrangement. A calculation, for instance, of the total electrode impedance under such conditions would give a completely erroneous picture.

For the considerations of the central current response in the case of invaded formations, the seriousness of the deviations of the prolate spheroid approximation will depend largely on the contrast in resistivity between the invaded zone and the undisturbed formation. Figure 1 shows schematically the actual current distribution through an invaded formation as compared with that assumed in the prolate spheroid method. In some regions the cross-section of current in the hyperboloid presentation will be too small, while in other regions it will be too large. The over-all error in the calculated apparent resistivity may therefore be in either direction and can only be ascertained by computation.

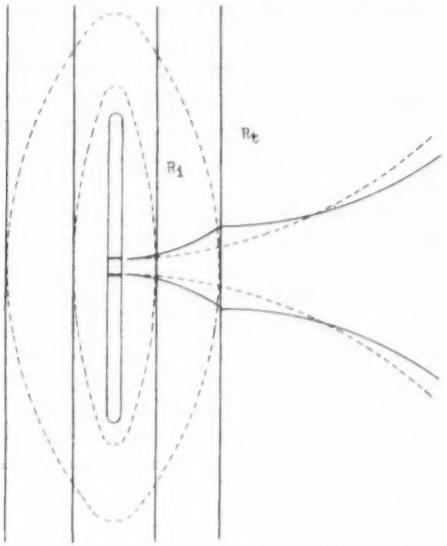

FIG. 1. Current distribution from central electrode in invaded formation.
——— Schematic of actual distribution
- - - - - - Hyperboloid distribution implied by prolate spheroid method.

The following sections will describe a method that permits the accurate computation of current distributions and apparent resistivities for a guard electrode arrangement.

GUARD ELECTRODE REPRESENTATION BY A SERIES OF INFINITELY CONDUCTIVE SPHERES

Let us consider first a single conducting sphere. In a homogeneous medium the current from such a sphere will be distributed equally in all directions. If we now add to the system two more spheres respectively above and below the first, emitting current in the same phase, there will be a focussing effect on the current distribution from the first sphere. This is the principle used in the laterolog (Doll). In laterologging the current from the adjacent electrodes is regulated so as to focus the central current essentially into the form of a horizontal current sheet. In guard electrode logging there is no such artificial regulation of the current from the adjacent electrodes. Here, the focussing is achieved by maintaining all electrodes at the same potential which is done by simple short circuiting. There will be no tendency for current to flow from one electrode to the other in the surrounding medium and, therefore, the current must flow laterally. The longer the adjacent electrodes (guards) the farther out the tendency of lateral focussing will be maintained. We can represent the guards by a series of adjacent spheres and calculate the current that must flow from each sphere in order to maintain the same potential at all the electrodes.

To derive the expressions for the current distribution let us assume that the cylindrical guard system of length $2L$ and diameter $2a$ is approximated by a series of $2n+1$ spheres of radius a. Let the spheres be equally spaced along the axis of the borehole so that the centers of the two outer spheres coincide with the intersection of the end planes of the guards and the borehole axis. The centers of two adjacent spheres are then a distance $s = 2L/2n$ apart. (See Figure 2.) Let the current from the central sphere be I_0, that from each one of the immediately adjacent pair I_1, that from each one of the following pair I_2, etc.

Let $(Ra)_s$ denote the apparent resistivity of a normal device consisting of two point electrodes with a spacing equal to s and similarly let $(Ra)_{js}$ denote the apparent resistivity of a normal device of spacing js. For simplicity, we shall first consider the case where $n = 1$ so that the total number of spheres is equal to 3.

The potential of the central sphere will be given by:

$$V_0 = \frac{I_0(Ra)_a}{4\pi a} + \frac{2I_1(Ra)_s}{4\pi s} \tag{1}$$

The potential of the two outer electrodes is:

$$V_1 = \frac{I_0}{4\pi}\left[\frac{(Ra)_s}{s} + \frac{I_1}{I_0}\left(\frac{(Ra)_a}{a} + \frac{(Ra)_{2s}}{2s}\right)\right] \tag{2}$$

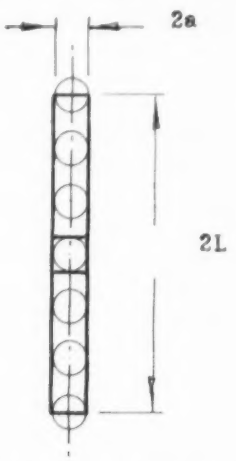

FIG. 2. Approximating guard electrode by $2n+1$ spheres. (In this figure $n=3$, ratio of diameter to length is exaggerated.)

Since the spheres must all be at the same potential, we have the condition that $V_0 = V_1$ which gives:

$$\frac{I_1}{I_0} = \frac{(Ra)_a/a - (Ra)_s/s}{(Ra)_a/a + (Ra)_{2s}/2s - 2(Ra)_s/s} \tag{3}$$

and

$$V_0 = \frac{I_0}{4\pi}\left[(Ra)_a/a + 2(Ra)_s/s\left(\frac{(Ra)_a/a - (Ra)_s/s}{(Ra)_a/a + (Ra)_{2s}/2s - 2(Ra)_s/s}\right)\right] \tag{4}$$

In a homogeneous medium equation (3) reduces to:

$$\left(\frac{I_1}{I_0}\right)_h = \frac{1/a - 1/s}{1/a + 1/2s - 2/s} \tag{5}$$

and the potential of the central electrode is:

$$(V_0)_h = \frac{I_0 R}{4\pi}\left[\frac{1}{a} + 2/s\left(\frac{1/a - 1/s}{1/a + 1/2s - 2/s}\right)\right] \tag{6}$$

where R is the resistivity of the homogeneous medium. Recalling now the definition of apparent resistivity as—that resistivity of a homogeneous medium, which for the same current I_0 gives the same potential V_0 as that observed in the heterogeneous case in question—we see from (4) and (6) that the apparent resistivity for our electrode arrangement in any heterogeneous medium is given by:

$$R_a = \frac{(Ra)_a/a + 2(Ra)_s/s\left[\dfrac{(Ra)_a/a - (Ra)_s/s}{(Ra)_a/a + (Ra)_{2s}/s - 2(Ra)_s/s}\right]}{1/a + 2/s\left(\dfrac{1/a - 1/s}{1/a + 1/2s - 2/s}\right)} \tag{7}$$

Expanding this analysis to the case of $2n+1$ electrodes where $n \leqq (2L/2a)$ we have for the i-th electrode:

$$V_i = \frac{I_0}{4\pi}\left[\frac{(Ra)_{ia}}{is} + \sum_{j=1}^{n}\frac{I_j}{I_0}\left(\frac{(Ra)_{|i-j|a}}{|i-j|s} + \frac{Ra_{(i+j)a}}{(i+j)s}\right)\right] \tag{8}$$

where $i = 0, 1, 2, \cdots, n$.

The condition $V_0 = V_1 = V_2 = \cdots = V_i = \cdots = V_n$ leads to n simultaneous equations for the n unknown quantities I_j/I_0.

Subtracting V_0 from V_i and dividing by $I_0/4\pi$ gives for the ith equation:

$$\sum_{j=1}^{n}\frac{I_j}{I_0}\left[\frac{(Ra)_{|i-j|a}}{|i-j|s} + \frac{(Ra)_{(i+j)a}}{(i+j)s} - \frac{2(Ra)_{ja}}{js}\right] = \frac{(Ra)_a}{a} - \frac{(Ra)_{ia}}{is}$$

The n equations are of the general form:

$$b_{i1}x_1 + \cdots + b_{ij}x_j + \cdots + b_{in}x_n = c_i$$

where

$$x_j \equiv \frac{I_j}{I_0} \qquad b_{ij} = \frac{(Ra)_{|i-j|a}}{|i-j|s} + \frac{(Ra)_{(i+j)a}}{(i+j)s} - \frac{2(Ra)_{ja}}{js}$$

$$c_i = \frac{(Ra)_a}{a} - \frac{(Ra)_{ia}}{is} \qquad \begin{cases} i \text{ from 1 to } n \\ j \text{ from 1 to } n \end{cases}$$

The solutions in determinant form are given by:

$$x_j = \frac{M_j}{D}$$

where

$$M_j = \begin{vmatrix} b_{11} & b_{12} \cdots c_1 \cdots b_{1n} \\ \cdot & \\ \cdot & \\ b_{n1} & b_{n2} \cdots c_n \cdots b_{nn} \end{vmatrix}$$

and

$$D = \begin{vmatrix} b_{11} & b_{12} \cdots b_{1j} \cdots b_{1n} \\ \cdot & \\ \cdot & \\ b_{n1} & b_{n2} \cdots b_{nj} \cdots b_{nn} \end{vmatrix}$$

For a homogeneous medium, we have similarly:

$$\left(\frac{I_j}{I_0}\right)_h \equiv x_j = \frac{(M_j)_h}{D_h}$$

where now

$$b_{ij} = \frac{1}{|i-j|s} + \frac{1}{(i+j)s} - \frac{2}{js}$$

and

$$c_i = \frac{1}{a} - \frac{1}{is}$$

The apparent resistivity of the electrode arrangement becomes:

$$R_a = \frac{(Ra)a/a + 2\sum_{j=1}^{n} x_j \frac{(Ra)_{js}}{js}}{1/a + 2\sum_{j=1}^{n} (x_j)_h/js} \tag{9}$$

The apparent resistivities for the constituent normal spacings can be obtained from departure curves for the normal devices, available in the literature.

COMPUTATIONAL RESULTS

Computations of apparent resistivities as given by equation (9) were carried out on an I.B.M. 650 magnetic drum data processing machine.

Figure 3 shows a plot of calculated apparent resistivities for increasing values of n for the case of a seven inch hole through a homogeneous formation with a

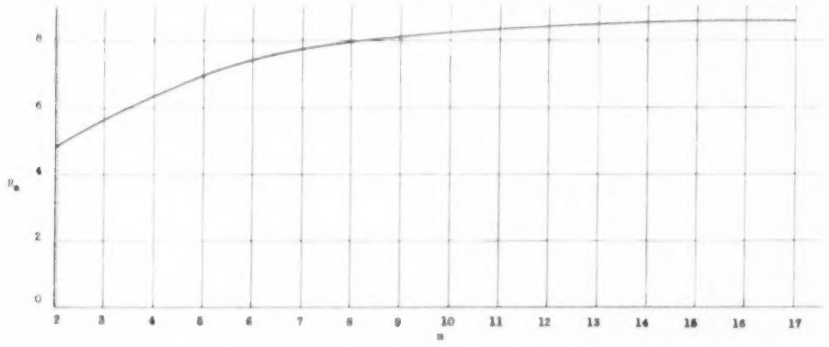

FIG. 3. Calculated apparent resistivities for increasing values of n. Hole diameter = 7"
$R_i = R_t = 10\ R_m$

TABLE I

R_t/R_m	D_c/d	R_a/R_m (Present Calculations)	R_a/R_m Prolate Spheroid	Percent Deviation
0.1	2.5	2.231	2.383	+ 6.8
0.1	5.0	3.722	3.970	+ 6.7
0.1	12.0	5.590	5.823	+ 4.2
1.0	2.5	2.779	2.941	+ 5.8
1.0	5.0	4.147	4.384	+ 5.7
1.0	12.0	5.867	6.069	+ 3.4
10.0	—	8.545	8.526	− 0.22
25.0	2.5	18.654	17.833	− 4.4
25.0	5.0	16.252	15.429	− 5.1
25.0	12.0	12.604	12.621	− 0.57
50.0	2.5	36.155	33.346	− 8.0
50.0	5.0	29.674	26.934	− 9.2
50.0	12.0	18.992	19.446	+ 2.3
120.0	2.5	87.486	76.781	−12.2
120.0	5.0	69.193	59.148	−14.5
120.0	12.0	34.178	38.556	+12.8
200.0	2.5	148.879	126.421	−15.1
200.0	5.0	116.381	95.964	−17.6
200.0	12.0	49.093	60.396	+23.0

resistivity ten times that of the drilling fluid. We note that a definite asymptotic value is attained at $n=17$. The apparent resistivity given by this asymptotic value is 8.545 times the resistivity of the drilling fluid. In these computations the total guard length was taken as 120 inches and the guard diameter as 3.5 inches.

For this same case the prolate spheroid approximation gives $R_a/R_m=8.526$, where R_m is the resistivity of the drilling fluid. Since for this small drill hole diameter the current from the central electrode is still essentially perpendicular to the drill hole axis when it reaches the boreface, the current refraction at the boreface has a negligible effect. As expected in this case, the result of the prolate spheroid approximation agrees to within a small fraction of one percent with our present calculations.

Even in larger holes the effects of refraction at the boreface will remain fairly insignificant, except possibly for the case where large caves occur.

For invaded formations the situation is more serious. When the current reaches the boundary of the invaded zone, the current pattern has already diverged sufficiently to undergo appreciable refraction. When the true formation resistivity, R_t, is larger than the invaded zone resistivity, R_i, current will refract toward the normal at the outer boundary of the invaded zone. The larger the ratio R_t/R_i the more tendency there will be for the current to diverge within the invaded zone and the sharper the refraction of the current pattern will be at the boundary. Depending on the invasion diameter, the combination of these two effects may cause either positive or negative errors in the results of the prolate spheroid approximation which may become as large as twenty percent.

When R_t is smaller than R_i, the overall contribution of the undisturbed formation to the electrode impedance will be small if there is appreciable invasion. The smaller R_t becomes with respect to R_i the sharper the refraction at the invaded zone boundary will be. At the same time, however, the contribution of the region beyond the invaded zone becomes less and less, so that the effects of changes in the current pattern in this region become smaller. The deviation in the prolate spheroid approximation for these cases often remains less than five percent.

Table I shows a listing of the present computations and the prolate spheroid approximation for the case of a 10 foot total guard length, a 3.5 inch guard diameter, a 7 inch hole diameter and an invaded zone resistivity $R_i = 10R_m$. In addition, the percentage deviations of the prolate spheroid approximation are given.

ACKNOWLEDGMENTS

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GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 75–88, 6 FIGS.

PROPAGATION OF TRANSIENT ELECTROMAGNETIC WAVES IN A MEDIUM OF FINITE CONDUCTIVITY*

BIMAL KRISHNA BHATTACHARYYA†

ABSTRACT

Transient electric and magnetic fields have been calculated for ramp function and sawtooth current sources immersed in a semi-conducting medium. An electric dipole source has been assumed. In the case of ramp function input, it is observed that the peaks of the overshoots in the θ-component of the electric field decrease in magnitude with the increase in rise time of the input pulse. It has also been shown that the rise time of the current pulses has definite effect upon the rise time and amplitude of the electric fields and that the sawtooth exciting pulses having large values of rise time may be conveniently used to obtain measurable values of the electric and magnetic fields.

INTRODUCTION

Attempts have been made by many geophysicists to utilise the propagation of transient electric pulses for exploration of the subsurface structure of the earth. The method is known as the "Eltran" method and is mainly electronic. As such, it is capable of being developed to a very high degree on account of the tremendous advancement in electronic instrumentation. Unfortunately, however, the theoretical side of the method has not yet been properly studied. A completely satisfactory theory for the interpretation of propagated field data is still lacking, though some attempt has been made in this direction. Wait (1951), for example, has calculated the transient electric fields for a step-function current source placed inside the earth assumed to be a semi-conducting medium. It is, however, to be noted that a source generating a step-function—an electric pulse jumping instantaneously from one value to another—is not physically realisable. On the other hand, a rising pulse which is sharp enough (a few microseconds) and which, with good approximation, may be represented by a linearly rising pulse front, is more common in practice. Such pulse fronts are, in fact, encountered in ramp-function and sawtooth type of current sources. Theoretical study of the effects produced by such pulse-fronts is, therefore, more important than that of the ideal one, the step function.

In this paper, transient electric and magnetic fields produced by ramp function and sawtooth current sources, immersed in a conducting medium, will be calculated. The source will be treated as an electric dipole. It will be shown that for the ramp function, the rise time of its current pulses has marked and definite effect upon the rise time and the amplitude of the electric fields produced. For the sawtooth pulse the magnitudes of the electric and magnetic fields are found to be negligibly small when the rise-time of the pulses is sharp (a few

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microseconds). It follows, therefore, that in order to have measurable effect, the risetime should be large (a few milliseconds).

We shall consider an electric dipole of length "*dl*" carrying a current $I(t)$ which is either of a ramp function type or of a sawtooth waveform.

THE ELECTRIC DIPOLE

Let the dipole be immersed in a homogeneous, isotropic medium having conductivity σ, dielectric constant ϵ, and permeability μ. Maxwell's equations, when written in m.k.s. units, are

$$\text{curl } \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t} \tag{1}$$

$$\text{curl } \vec{H} = \sigma \vec{E} + \epsilon \frac{\partial \vec{E}}{\partial t} \tag{2}$$

$$\text{div } \vec{D} = \rho \tag{3}$$

and

$$\text{div } \vec{B} = 0 \tag{4}$$

where $\vec{E}$ and $\vec{H}$ denote the electric and magnetic field intensities, $\vec{D}$ is the electric displacement and $\vec{B}$ the magnetic induction. Let $I(t)$ be the impressed current density. If we denote the Laplace transform of $V(t)$ by $v(s)$, we obtain, by taking the Laplace transforms of Eqs. (1) and (2),

$$\text{curl } e(s) = -\mu s h(s) \tag{5}$$

and

$$\text{curl } h(s) = (\sigma + \epsilon s)e(s) + i(s). \tag{6}$$

Now the field intensities may be expressed in terms of a single parameter, the vector Hertz potential $\pi(s)$, by the following relations:

$$e(s) = \text{grad div } \pi(s) - \gamma^2 \pi(s) \tag{7}$$

and

$$h(s) = (\sigma + \epsilon s) \text{ curl } \pi(s) \tag{8}$$

where

$$\gamma^2 = (\sigma\mu s + \epsilon\mu s^2).$$

If we assume the dipole to be oriented in the z-direction, we may easily write down the Laplace transform $\pi(s)$ of the vector Hertz potential $\pi(t)$ in the following way (Wait, 1951):

$$\pi_z(s) = \frac{i(s)dl}{4\pi(\sigma + \epsilon s)} \cdot \frac{e^{-\gamma r}}{r} \tag{9}$$

$$\pi_x(s) = 0 \quad \text{and} \quad \pi_y(s) = 0.$$

Let us assume that the displacement currents are negligible in comparison with the conduction currents. Then, in the expressions (8) and (9), $(\sigma+\epsilon s)$ may be replaced by σ. This assumption makes the problem of determining the inverse transform of the expressions obtained somewhat simpler.

With the aid of Eq. (9), we obtain the following expression for $\pi(s)$ in spherical co-ordinates (Fig. 1a):

$$\pi(s) = \frac{i(s)dl}{4\pi\sigma} \cdot \frac{e^{-\gamma r}}{r} \cos\theta \vec{i}_1 - \frac{i(s)dl}{4\pi\sigma} \cdot \frac{e^{-\gamma r}}{r} \sin\theta \cdot \vec{i}_2 \tag{10}$$

where $\vec{i}_1$ and $\vec{i}_2$ are unit vectors in the increasing r and θ directions.

Utilizing Eqs. (7), (8) and (10), we may write the expressions for the non-vanishing field components:

$$e_r(s) = \frac{i(s)dl}{2\pi\sigma r^3}(1 + \alpha s^{1/2})e^{-\alpha s^{1/2}} \cos\theta, \tag{11}$$

$$e_\theta(s) = \frac{i(s)dl}{4\pi\sigma r^3}(1 + \alpha s^{1/2} + \alpha^2 s)e^{-\alpha s^{1/2}} \sin\theta \tag{12}$$

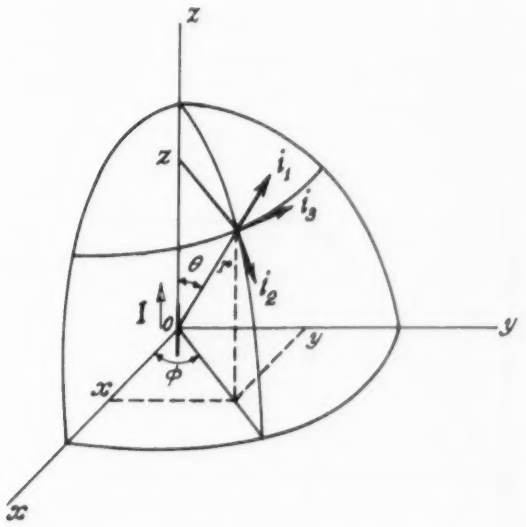

FIG. 1a. Spherical coordinate system showing the position of the dipole at the origin oriented in the z direction.

and

$$h_\phi(s) = \frac{i(s)dl}{4\pi r^2}(1 + \alpha s^{1/2})e^{-\alpha s^{1/2}} \sin\theta \tag{13}$$

where

$$\alpha^2 = \sigma\mu r^2.$$

A CURRENT SOURCE OF RAMP FUNCTION TYPE

Let us now assume that the current $I(t)$ in the dipole is of ramp function type (Fig. 1b) which may be analytically represented by

$$I(t) = I\left[\frac{t}{t_1}u(t) - \frac{(t-t_1)}{t_1}u(t-t_1)\right] \tag{14}$$

where t_1 is the time taken by the current to rise from its zero value to the final amplitude I and $U(t)$ and $U(t-t_1)$ are the step functions beginning at times $t=0$ and $t=t_1$ respectively.

So we have,

$$i(s) = \frac{I}{t_1}\cdot\frac{(1-e^{-st_1})}{s^2}. \tag{15}$$

Expression for $E_r(t)$:

Substituting equation (15) into (11), we have

$$e_r(s) = \frac{Idl\cos\theta}{2\pi\sigma r^3 t_1}\cdot\frac{(1+\alpha s^{1/2})e^{-\alpha s^{1/2}}}{s^2}\cdot(1-e^{-st_1}). \tag{16}$$

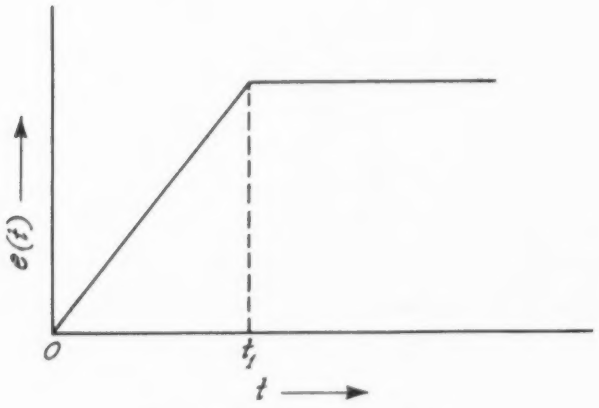

FIG. 1b. A ramp-function type of pulse.

From the theory of Laplace transforms we know that if $x(s)$ is the transform of $x(t)$ and m is a real positive number, then $(1/m)x(s/m)$ is the transform of $x(mt)$. Put $m = 1/\alpha^2$. The $\alpha^2 x(\alpha^2 s)$ is the transform of $x(t/\alpha^2)$. Equation (16) may be written in the form:

$$e_r(s) = \frac{Idl\cos\theta}{2\pi\sigma r^3}\cdot\alpha^2\cdot\frac{\alpha^2}{t_1}\cdot\frac{1+(\alpha^2 s)^{1/2}}{(\alpha^2 s)^2}\cdot e^{-(\alpha^2 s)^{1/2}}\cdot\left[1-e^{-\alpha^2 s\cdot t_1/\alpha^2}\right]. \tag{17}$$

So we can normalize (17), by substituting

$$\tau \equiv \frac{t}{\alpha^2}, \qquad e_r(s) \equiv \frac{e_r(s)\cdot 2\pi\sigma r^3}{Idl\cos\theta} \quad \text{and} \quad t_r \equiv \frac{t_1}{\alpha^2}.$$

We, then, obtain

$$e_r(s) = \frac{1}{t_r}\cdot\frac{(1+s^{1/2})\cdot e^{-s^{1/2}}}{s^2}\cdot(1-e^{-st_r}). \tag{18}$$

From equation (18) it is evident that the inverse Laplace transform of $e_r(s)$ may be expressed as

$$E_r(\tau) = \frac{1}{t_r}\left[e_r(\tau)u(\tau) - e_r(\tau-t_r)u(\tau-t_r)\right]. \tag{19}$$

Hence,

$$L[e_r(\tau)] = \frac{e^{-s^{1/2}}}{s^2} + \frac{e^{-s^{1/2}}}{s^{3/2}} \tag{20}$$

From the table in the Appendix, we have

$$L^{-1}\left(\frac{e^{-s^{1/2}}}{s^{3/2}}\right) = \frac{2}{\sqrt{\pi}}\tau^{1/2} - 1 + \frac{2}{\sqrt{\pi}}\frac{1}{2\sqrt{\tau}}\left[\frac{1}{2} - \frac{1}{3\cdot 4}\left(\frac{1}{2\sqrt{\tau}}\right)^2 + \frac{1}{2!}\frac{1}{5\cdot 6}\left(\frac{1}{2\sqrt{\tau}}\right)^4 - \frac{1}{3!}\frac{1}{7\cdot 8}\left(\frac{1}{2\sqrt{\tau}}\right)^6 + \cdots\right]. \tag{21}$$

and

$$L^{-1}\left(\frac{e^{-s^{1/2}}}{s^2}\right) = \tau - \frac{2}{\sqrt{\pi}}\tau^{1/2} + \frac{1}{2} - \frac{1}{\sqrt{\pi\tau}}\left[\frac{1}{2\cdot 3} - \frac{1}{3\cdot 4\cdot 5}\left(\frac{1}{2\sqrt{\tau}}\right)^2 + \frac{1}{2!}\frac{1}{5\cdot 6\cdot 7}\left(\frac{1}{2\sqrt{\tau}}\right)^4 - \frac{1}{3!}\frac{1}{7\cdot 8\cdot 9}\left(\frac{1}{2\sqrt{\tau}}\right)^6 + \cdots\right]. \tag{22}$$

Substituting (21) and (22) into (20), we have

$$e_r(\tau) = \left(\tau - \frac{1}{2}\right) + \frac{1}{\sqrt{\pi\tau}}\left[\left(\frac{1}{2} - \frac{1}{2\cdot 3}\right) - \left(\frac{1}{3\cdot 4} - \frac{1}{3\cdot 4\cdot 5}\right)\left(\frac{1}{2\sqrt{\tau}}\right)^2 + \frac{1}{2!}\left(\frac{1}{5\cdot 6} - \frac{1}{5\cdot 6\cdot 7}\right)\left(\frac{1}{2\sqrt{\tau}}\right)^4 - \cdots\right]. \tag{23}$$

The expressions within square brackets may be written

$$u = u_1 + u_2 + \cdots + u_n + \cdots \tag{24}$$

where

$$\begin{aligned} u_n &= (-1)^{n+1} \cdot \frac{1}{(n-1)!} \cdot \left(\frac{1}{2\sqrt{\tau}}\right)^{2(n-1)} \cdot \frac{1}{2}\left[\frac{1}{(2n-1)} - \frac{1}{(2n+1)}\right] \cdot \\ &= u_n^{(1)} - u_n^{(2)}. \end{aligned} \tag{25}$$

In Eq. (25)

$$u_n^{(1)} = (-1)^{n+1} \cdot \frac{1}{(n-1)!} \left(\frac{1}{2\sqrt{\tau}}\right)^{2(n-1)} \cdot \frac{1}{2(2n-1)}$$

and

$$u_n^{(2)} = (-1)^{n+1} \cdot \frac{1}{(n-1)!} \left(\frac{1}{2\sqrt{\tau}}\right)^{2(n-1)} \cdot \frac{1}{2(2n+1)}.$$

Thus the series in (24) may be expressed as the sum of two different series

$$u = u^{(1)} - u^{(2)} \tag{26}$$

where

$$\begin{aligned} u^{(1)} &= \frac{1}{2} \sum_{n=1}^{\infty} (-1)^{n+1} \cdot \frac{1}{(n-1)!} \cdot \left(\frac{1}{2\sqrt{\tau}}\right)^{2(n-1)} \cdot \frac{1}{(2n-1)} \\ &= \frac{1}{2}\left[1 - \frac{x^2}{3} + \frac{x^4}{2! \cdot 5} - \frac{x^6}{3! \cdot 7} + \cdots\right] \end{aligned} \tag{27}$$

and

$$\begin{aligned} u^{(2)} &= \frac{1}{2} \sum_{n=1}^{\infty} (-1)^{n+1} \cdot \frac{1}{(n-1)!} \cdot \left(\frac{1}{2\sqrt{\tau}}\right)^{2(n-1)} \cdot \frac{1}{(2n+1)} \\ &= \frac{1}{2}\left[\frac{1}{3} - \frac{x^2}{5 \cdot 1!} + \frac{x^4}{7 \cdot 2!} - \frac{x^6}{9 \cdot 3!} + \cdots\right]. \end{aligned} \tag{28}$$

In equations (27) and (28),

$$x = 1/2\sqrt{(\tau)}.$$

Since the error function "erf (x)" is given by

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}}\, x\left[1 - \frac{x^2}{3} + \frac{x^4}{2! \cdot 5} - \frac{x^6}{3! \cdot 7} + \cdots\right] \tag{29}$$

we have, by comparing (27) with (29),

$$u^{(1)} = \frac{\sqrt{\pi}}{4} \cdot \frac{\text{erf}\,(x)}{x}. \tag{30}$$

Integrating both sides of (28) with respect to x^2, we have

$$\int u^{(2)} dx^2 = \frac{1}{2}\left[\frac{x^2}{3} - \frac{x^4}{5 \cdot 2!} + \frac{x^6}{7 \cdot 3!} - \cdots\right] + A, \tag{31}$$

where A is a constant.
With the help of (29) and (31), we may write

$$\text{erf}\,(x) = \frac{2}{\sqrt{\pi}}\, x\left[1 - 2\int u^{(2)} dx^2 - A\right]. \tag{32}$$

Solving (32), $u^{(2)}$ may be expressed as

$$u^{(2)} = \frac{\sqrt{\pi}}{8x^3}\,\text{erf}\,(x) - \frac{\sqrt{\pi}}{8x^2}\,\text{erf}'\,(x). \tag{33}$$

Now, with the aids of equations (23), (26), (30) and (33), $e_r(\tau)$ may be written in the following closed form:

$$e_r(\tau) = \left(\tau - \frac{1}{2}\right) + \frac{1}{4}\left[(2 - 4\tau)\,\text{erf}\left(\frac{1}{2\sqrt{\tau}}\right) + 2\tau^{1/2}\,\text{erf}'\left(\frac{1}{2\sqrt{\tau}}\right)\right]. \tag{34}$$

Now, equation (19) may be utilized to express $E_r(\tau)$ in the following way for two separate time-domains:

(i) $0 \leqq \tau \leqq t_r$,

$$E_r(\tau) = \frac{1}{t_r}\left[\left(\tau - \frac{1}{2}\right) + \frac{1}{4}\left\{(2 - 4\tau)\,\text{erf}\left(\frac{1}{2\sqrt{\tau}}\right) + 2\tau^{1/2}\,\text{erf}'\left(\frac{1}{2\sqrt{\tau}}\right)\right\}\right] \tag{35}$$

and

(ii) $\tau \geqq t_r$,

$$E_r(\tau) = \frac{1}{t_r}\left[e_r(\tau)u(\tau) - e_r(\tau - t_r)u(\tau - t_r)\right]. \tag{36}$$

A plot of $E_r(\tau)$ against τ is given in Fig. 2. It is well to recall here that τ is the time scale normalised with respect to $\sigma\mu r^2$. The field intensities have been plotted

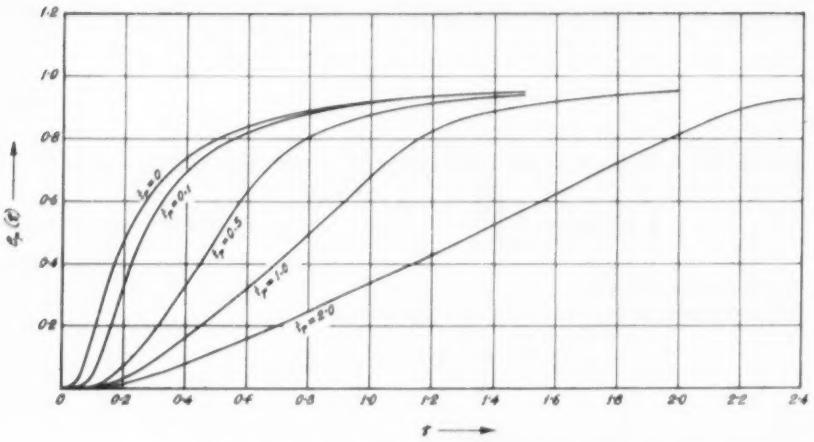

FIG. 2. Radial electric field component as function of time for various build-up time of the input pulse.

for four different values of t_r e.g. (i) $t_r=0.1$, (ii) $t_r=0.5$, (*iii*) $t_r=1.0$ and (iv) $t_r=2.0$. The plot of the field intensity for a step function input (Wait, 1951) has also been included in Fig. 2 to depict clearly the change in the nature of the field intensity with the variation of steepness of pulse-fronts.

Expression for $E_\theta(\tau)$

Substituting (15) into (12) we obtain an expression for $e_\theta(s)$:

$$e_\theta(s) = \frac{Idl \sin\theta}{4\pi\sigma r^3 t_1} \cdot \frac{e^{-\alpha s^{1/2}}}{s^2} \cdot [1 + \alpha s^{1/2} + \alpha^2 s] \cdot (1 - e^{-s t_1}). \tag{37}$$

Normalizing (37), we have

$$e_\theta(s) = \frac{1}{t_r} \cdot \frac{e^{-\alpha s^{1/2}}}{s^2} \cdot (1 + s^{1/2} + s)(1 - e^{-s t_r}). \tag{38}$$

From (38), it is evident that

$$E_\theta(\tau) = \frac{1}{t_r} [e_\theta(\tau)u(\tau) - e_\theta(\tau - t_r)u(\tau - t_r)]. \tag{39}$$

So, $e_\theta(\tau)$ is given by

$$e_\theta(\tau) = L^{-1}\left[\frac{e^{-\alpha s^{1/2}}}{s^2}(1 + s^{1/2} + s)\right]. \tag{40}$$

Since

$$L^{-1}\frac{e^{-s^{1/2}}}{s} = 1 - \operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right) \tag{41}$$

We may write with the aid of equations (21), (22) and (41),

$$e_\theta(\tau) = \left(\tau - \frac{1}{2}\right) + \frac{1}{4}\left[(2 - 4\tau)\operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right) + 2\tau^{1/2}\operatorname{erf}'\left(\frac{1}{2\sqrt{\tau}}\right)\right] + \left[1 - \operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right)\right]. \tag{42}$$

Substituting (42) into (39), we have

(i) $0 \leqq \tau \leqq t_r$,

$$E_\theta(\tau) = \frac{1}{t_r}\left[\left(\tau - \frac{1}{2}\right) + \frac{1}{4}\left\{(2 - 4\tau)\operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right) + 2\tau^{1/2}\operatorname{erf}'\left(\frac{1}{2\sqrt{\tau}}\right)\right\} + 1 - \operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right)\right] \tag{43}$$

and (ii) $\tau \geqq t_r$,

$$E_\theta(\tau) = \frac{1}{t_r}\left[e_\theta(\tau)u(\tau) - e_\theta(\tau - t_r)u(\tau - t_r)\right]. \tag{44}$$

$E_\theta(\tau)$ has been plotted in Fig. 3 as a function of τ for four different values of t_r.

Expression for $H_\phi(\tau)$

Following a similar procedure as outlined in the determination of $E_r(\tau)$ and $E_\theta(\tau)$, we obtain the following expressions for $H_\phi(\tau)$:

(i) $0 \leqq \tau \leqq t_r$,

$$H_\phi(\tau) = \frac{1}{t_r}\left[\left(\tau - \frac{1}{2}\right) + \frac{1}{4}\left\{(2 - 4\tau)\operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right) + 2\tau^{1/2}\operatorname{erf}'\left(\frac{1}{2\sqrt{\tau}}\right)\right\}\right] \tag{45}$$

and

(ii) $\tau \geqq t_r$

$$H_\phi(\tau) = \frac{1}{t_r}\left[h_\phi(\tau)u(\tau) - h_\phi(\tau - t_r)u(\tau - t_r)\right] \tag{46}$$

where $h_\phi(\tau)$ is given by the expression within the square brackets in (45). It is

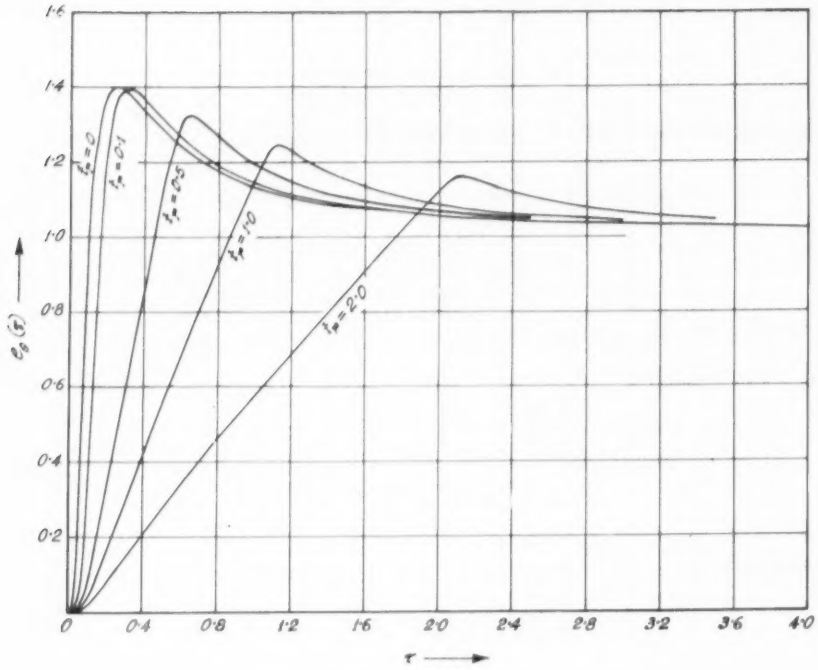

FIG. 3. A plot of $E_\phi(\tau)$ against time.

evident that the expressions for $H_\phi(\tau)$ are identical with those obtained in the case of $E_r(\tau)$.

A CURRENT SOURCE OF SAWTOOTH WAVEFORM

A sawtooth waveform (Fig. 4) may be analytically represented by

$$i(t) = \frac{t}{t_1}\,[u(t) - u(t - t_1)]. \tag{47}$$

The Laplace transform of $i(t)$ is given by

$$i(s) = \frac{1 - e^{-st_1}}{s^2 t_1} - \frac{e^{-st_1}}{s}. \tag{48}$$

From (48) it is evident that $(1-e^{-st_1})/s^2t_1$ corresponds to a ramp function current source with build-up time t_1 and e^{-st_1}/s is the Laplace transform of a step-function current beginning at time $t=t_1$.

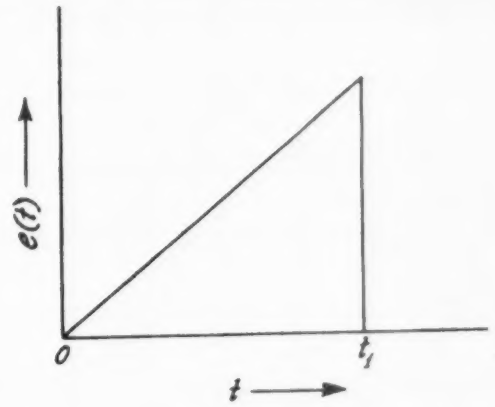

FIG. 4. A sawtooth pulse.

Expression for $E_r(\tau)$:

When a step-function current is fed into a conducting medium, $e_r(\tau)$ is given by (Wait, 1951):

$$e_r(\tau) = 1 - \operatorname{erf}\left(\frac{1}{2\tau^{1/2}}\right) + \left(\frac{1}{2\tau^{1/2}}\right)\operatorname{erf}'\left(\frac{1}{2\tau^{1/2}}\right). \tag{49}$$

So with the help of (34), (48) and (49) we may now express $E_r(\tau)$ in the following way:

(i) $0 \leqq \tau \leqq t_r$,

$$E_{r1}(\tau) = \frac{1}{t_r}\left[\left(\tau - \frac{1}{2}\right) + \frac{1}{4}\left\{(2 - 4\tau)\operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right) + 2\tau^{1/2}\operatorname{erf}'\left(\frac{1}{2\sqrt{\tau}}\right)\right\}\right] \tag{50}$$

and

(ii) $\tau \geqq t_r$,

$$E_{r2}(\tau) = E_{r1}(\tau)u(\tau) - E_{r1}(\tau - t_r)u(\tau - t_r) - \left[1 - \operatorname{erf}\left\{\frac{1}{2(\tau - t_r)^{1/2}}\right\} + \left\{\frac{1}{2(\tau - t_r)^{1/2}}\right\}\operatorname{erf}'\left\{\frac{1}{2(\tau - t_r)^{1/2}}\right\}\right]u(\tau - t_r). \tag{51}$$

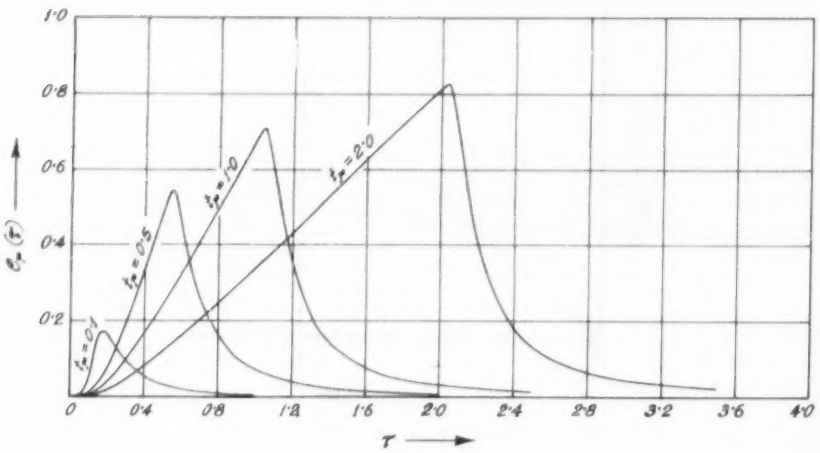

FIG. 5. A plot of $E_\tau(\tau)$ against time.

A plot of $E_\tau(\tau)$ versus τ is given in Fig, 5 for different values of t_τ.

Expression for $E_\theta(\tau)$:

For a step-function current input at $\tau = 0$, $e_\theta(\tau)$ is given by

$$e_\theta(\tau) = 1 - \operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right) + \left\{\left(\frac{1}{2\sqrt{\tau}}\right) + 2\left(\frac{1}{2\sqrt{\tau}}\right)^3\right\} \operatorname{erf}'\left(\frac{1}{2\sqrt{\tau}}\right). \tag{52}$$

So the E_θ-component of the electric field corresponding to a sawtooth current input may be written in the following form with the help of (43), (48) and (52).

(i) $0 \leqq \tau \leqq t_\tau$,

$$E_{\theta 1}(\tau) = \frac{1}{t_\tau}\left[\left(\tau - \frac{1}{2}\right) + \frac{1}{4}\left\{(2 - 4\tau)\operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right) + 2\tau^{1/2}\operatorname{erf}'\left(\frac{1}{2\sqrt{\tau}}\right)\right\} + 1 - \operatorname{erf}\left(\frac{1}{2\sqrt{\tau}}\right)\right] \tag{53}$$

and

(ii) $\tau \geqq t_\tau$,

$$E_{\theta 2}(\tau) = E_{\theta 1}(\tau)u(\tau) - E_{\theta 1}(\tau - t_\tau)u(\tau - t_\tau) - \left[1 - \operatorname{erf}\left\{\frac{1}{2(\tau - t_\tau)^{1/2}}\right\} + \left\{\frac{1}{2(\tau - t_\tau)^{1/2}} + 2\left(\frac{1}{2(\tau - t_\tau)^{1/2}}\right)^3\right\} \operatorname{erf}'\left\{\frac{1}{2(\tau - t_\tau)^{1/2}}\right\}\right]. \tag{54}$$

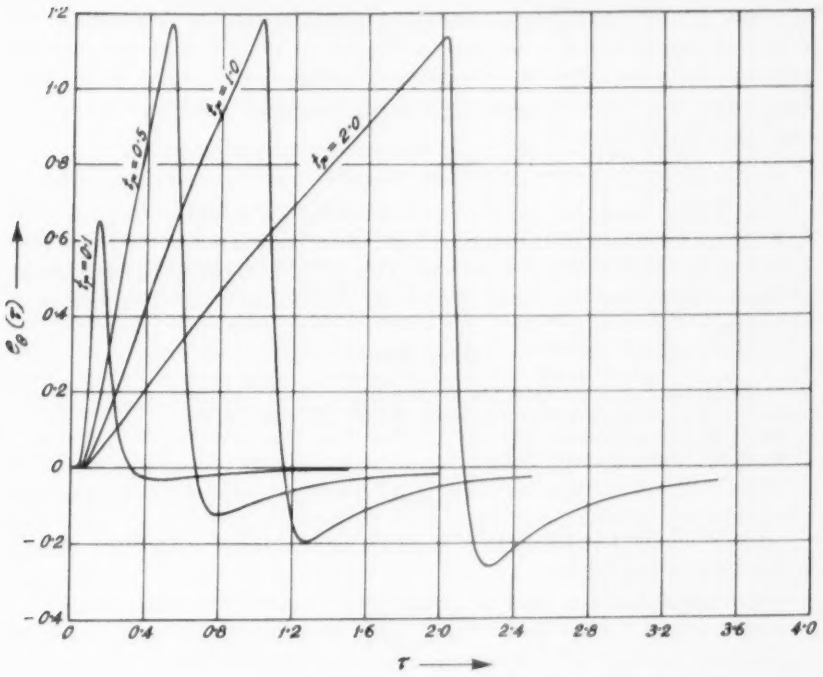

FIG. 6. A plot of $E_\theta(\tau)$ against time.

The expression within square brackets is the response function to a step-function current input starting at time $\tau = \tau_r$. Figure 6 shows the variation of $E_\theta(\tau)$ with the normalized time-function.

The only non-vanishing component of the magnetic field, $H_\phi(\tau)$ is given by an expression identical to that of $E_r(\tau)$ which has already been deduced in equations (50) and (51).

DISCUSSION

When a pulse of ramp-function type is radiated into a semi-conducting medium, the non-vanishing components of the electric and magnetic field intensities exhibit time-gradients which vary somewhat with the change in steepness of the exciting pulse-fronts. Thus, in the case of $E_\theta(\tau)$, the magnitude of the overshoots (Fig. 3) begins to decrease as the rise time t_r of the ramp-function pulse becomes longer. The field intensities assume the peak normalized values at different times depending upon t_r. It follows therefore that for studying with the pulses of ramp-function type one should use fast oscilloscopes and make the rise time of the ramp-function chosen as sharp as possible.

In the case of sawtooth pulse, $E_\theta(\tau)$ has a negative overshoot. Its magnitude

decreases as t_r decreases (Figs. 5 and 6). A sawtooth pulse of very small t_r behaving as impulse function, will not be propagated at all in a semi-conducting medium. Hence for the work of geophysical exploration, sawtooth pulses with large values of t_r should be used for obtaining measurable magnitudes of electric and magnetic field intensities.

ACKNOWLEDGEMENT

The author takes this opportunity of recording his grateful thanks to Prof. S. K. Mitra for helpful discussions in course of the preparation of the paper. The author is also thankful to Dr. J. N. Bhar, D.Sc., F.N.I., Head of the Department of Radio Physics and Electronics, University of Calcutta for his keen interest in the work.

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APPENDIX

A table of the Laplace-transform mates that have been frequently used in this paper is given below:

(i) $$\frac{\exp(-\alpha s^{1/2})}{s} \doteqdot \left[1 - \operatorname{erf}\left(\frac{\alpha}{2\sqrt{t}}\right)\right]$$

(ii) $$\frac{\exp(-\alpha s^{1/2})}{s^{1/2}} \doteqdot \left[\frac{1}{2\sqrt{t}} \operatorname{erf}'\left(\frac{\alpha}{2\sqrt{t}}\right)\right]$$

(iii) $$\exp(-\alpha s^{1/2}) \doteqdot \left[\frac{2\alpha}{(2t^{1/2})^3} \operatorname{erf}'\left(\frac{\alpha}{2\sqrt{t}}\right)\right]$$

(iv) $$\frac{\exp(-\alpha s^{1/2})}{s^{3/2}} \doteqdot \left[\frac{2t^{1/2}}{\sqrt{\pi}} - \alpha + \frac{2}{\sqrt{\pi}} \cdot \frac{\alpha^2}{2\sqrt{t}} \left\{\frac{1}{2} - \frac{1}{3 \cdot 4}\left(\frac{\alpha}{2\sqrt{t}}\right)^2 + \frac{1}{2!} \cdot \frac{1}{5 \cdot 6}\left(\frac{\alpha}{2\sqrt{t}}\right)^4 - \cdots\right\}\right]$$

(v) $$\frac{\exp(-\alpha s^{1/2})}{s^2} \doteqdot \left[t - \frac{2\alpha}{\sqrt{\pi}} t^{1/2} + \frac{\alpha^2}{2} - \frac{2}{\sqrt{\pi}}\left(\frac{\alpha^3}{2\sqrt{t}}\right)\left\{\frac{1}{2 \cdot 3} - \frac{1}{3 \cdot 4 \cdot 5}\left(\frac{\alpha}{2\sqrt{t}}\right)^2 + \frac{1}{2!} \cdot \frac{1}{5 \cdot 6 \cdot 7}\left(\frac{\alpha}{2\sqrt{t}}\right)^4 - \cdots\right\}\right].$$

In all these expressions the "error function" erf (x) has been defined to be

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}}\left[x - \frac{x^3}{1! \cdot 3} + \frac{x^5}{2! \cdot 5} - \frac{x^7}{3! \cdot 7} + \cdots\right].$$

GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 89–103, 10 FIGS.

GEOPHYSICAL ACTIVITY IN 1955*

HOMER G. PATRICK†

I. THE PETROLEUM INDUSTRY

In accordance with the indicated trend of geophysical activity reported by Dr. Sigmund Hammer in the Interim Report to Midyear[1] the world-wide exploratory effort in search of petroleum was increased in 1955 over that of the previous year. It is to be understood that the information concerning *world-wide* or *global* activities is incomplete as there are still some parts of the world from which no statistical data are available. An average of 1119 geophysical crews of all types were reported as actively engaged in exploratory work during 1955. This is an increase of 83 crews over the number reported in 1954, and it is slightly higher than the previous record high of 1105 crews in 1953.

Table I shows the global distribution of geophysical activities during 1955, by area and by method, and rate comparisons with the statistics for 1954. Activity in seismic and gravity work in the United States increased slightly, while magnetic exploration decreased by 30 per cent compared to the previous year. Slight decreases in all methods were reported in Canada. Geophysical exploration in the entire western hemisphere was up slightly (1.4 percent) over 1954.

Major increases in the use of all methods of geophysical exploration were reported in the eastern hemisphere. While 1955 was perhaps the biggest year on record for exploration work in the eastern hemisphere the large rate increases, 40.6 percent in seismic, 73.9 percent in gravity, 143.7 percent in magnetic and 71.4 percent in other methods, may be due in part to the incompleteness of the 1954 statistical data. On a world-wide basis gravity meter exploration rose 23.6 percent, seismic work was up 6.2 percent, magnetic work up 34.0 percent, while exploration by other methods showed a 61.9 percent decline.

Figure 1 shows the monthly variations in seismic and gravity activities in the United States during the past twelve years. The downward trend in seismic operations which began in the fall of 1952, following a long period of increasing activity, was reversed in late 1954 and continued upward during the year 1955. An average of 591 seismic crews operated in the United States during 1955 as compared to a yearly average of 572 crews in 1954. The slight increase of 3.3 percent in overall seismic activity in 1955 as compared to the previous year indicates the decline in activity noted during 1954 was regained in 1955. Gravity operations in the United States during the year 1955 continued at a slightly

* Report of the Standing Committee on Geophysical Activity of the Society of Exploration Geophysicists. The members of the committee are: Kenneth L. Cook, R. J. Copeland, Santos Figueroa Huerta, W. W. Hardy, Herbert Hoover, Jr., C. N. Hurry, Kumiji Iida, C. C. Lister, and Homer G. Patrick, Chairman.

† Humble Oil & Refining Company, Houston, Texas.

[1] GEOPHYSICS, Vol. XXI, No. 1 (January, 1956), pp. 179–191.

TABLE I

CREW-MONTHS OF GEOPHYSICAL EXPLORATION FOR PETROLEUM

	U.S.A.			Canada			Western Hemisphere			Eastern Hemisphere			World		
	1954	1955	Percent Change	1954	1955	Percent Change	1954	1955	Percent Change	1954	1955	Percent Change	1954	1955	Percent Change
Seismic	6,863	7,090	+ 3.3	1,535	1,496	−2.5	9,209	9,395	+ 2.0	1,130	1,589	+40.6	10,339	10,984	+ 6.2
Gravity	997	1,074	+ 7.7	108	103	−4.6	1,302	1,431	+ 9.0	357	621	+73.9	1,659	2,052	+23.6
Magnetic	109	76	−30.3	9	—	—	158	146	− 7.5	71	173	+143.7	238	319	+34.0
Other	—	—	—	—	—	—	162	15	−90.7	35	60	+71.4	197	75	−61.9
Total	7,969	8,240	+ 3.4	1,652	1,599	−3.2	10,831	10,987	+ 1.4	1,593	2,443	+53.4	12,433	13,430	+ 8.0

FIG. 1. Monthly variations in seismograph and gravimeter crew-months in the U.S.A.

higher rate than in 1954. The number of gravity crews in operation averaged 90 in 1955 compared to an average of 83 crews in 1954.

Geophysical activities by the seismic and gravity methods in Canada during the past nine years are shown in Figure 2. Recent years, 1954 and 1955 in particular, are characterized by considerable seasonal fluctuation in activity. Transportation difficulties, beginning with the spring thaws and continuing during the summer months, account for the decreased activity during those periods. The number of seismic crews engaged in Canadian exploration during 1955 reached 150 in March, dropped to 100 in April, and reached a year-end peak of 164. The 1955 average was 124 crews, compared to an average of 128 crews in 1954. Gravity work continued throughout 1955 at approximately the same level as in

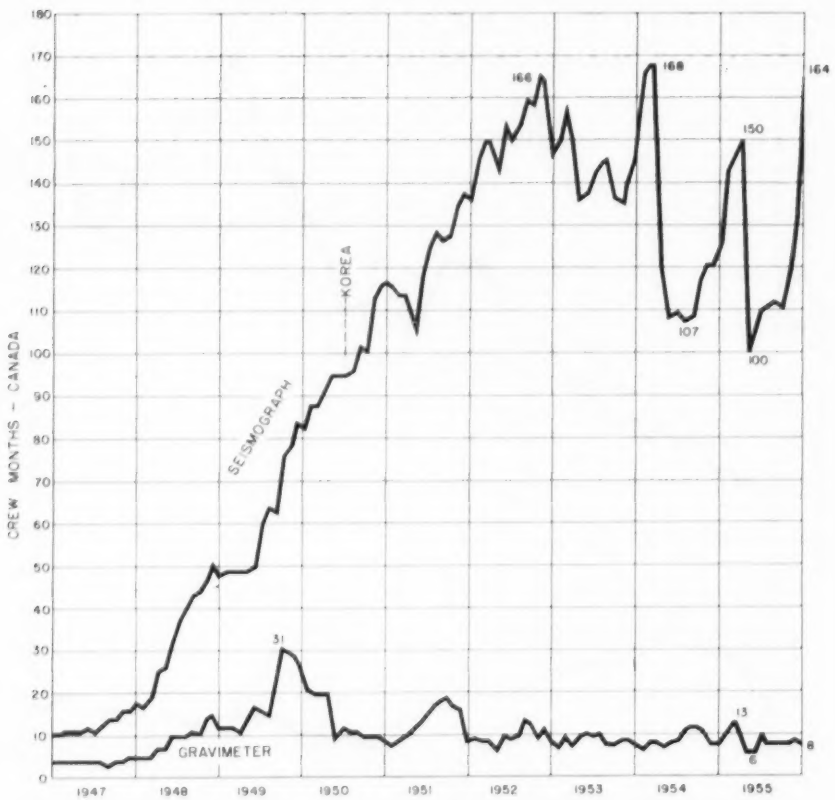

FIG. 2. Monthly variations in seismograph and gravimeter crew-months in Canada.

the past three years. An average of 8.5 gravity crews operated in Canada during the year. No magnetic work was reported in Canada in 1955. It is estimated that more than two-thirds, and possibly as much as three-fourths, of all geophysical work done in Canada during 1955 was done by contractors.

The geographic distribution of the seismic activity during 1955 in the United States is shown in Figure 3. The percentage figures shown on the chart indicate the percent of the total seismic work reported in the United States during the year. The (+) and (−) signs in this chart, as well as in the charts to follow, indicate increases or decreases in relative concentration of effort in 1955 as compared to 1954. It will be noted that there was increased activity in both Texas and Louisiana and that these two states continue to be the favored hunting ground, accounting for 56.5 percent of all seismic work done in the United States. Heretofore, geophysics exploration activities in the waters of the Gulf of Mexico

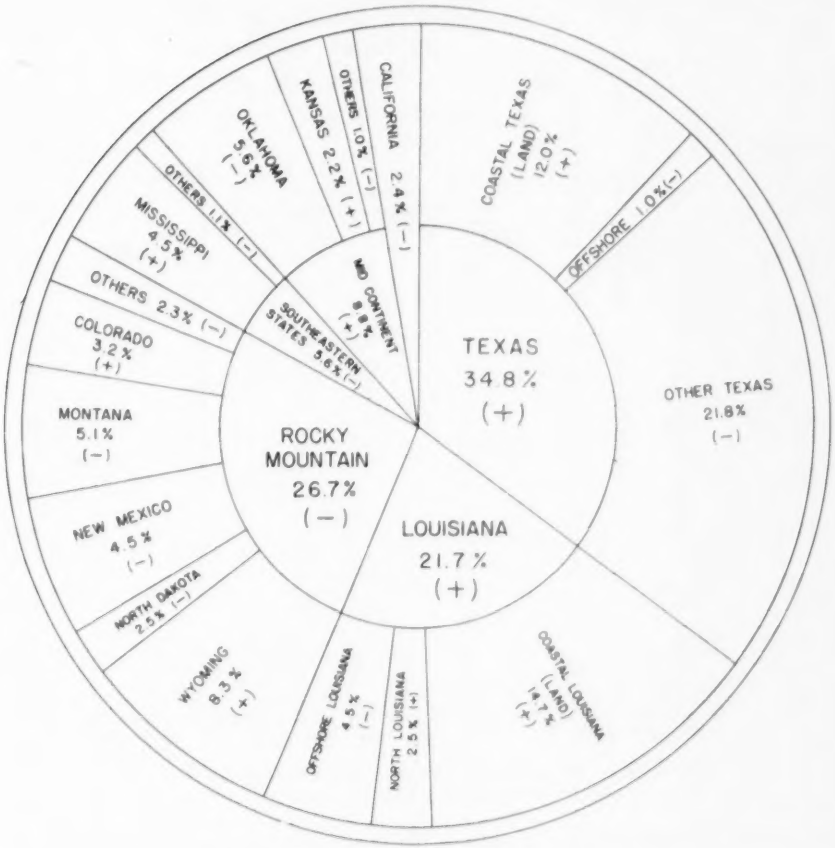

FIG. 3. Distribution of seismograph prospecting in the U.S.A. in 1955.

have been included in the coastal Louisiana and coastal Texas portions of the report. Due to the increased interest in the activity in the region, operations in the Gulf of Mexico are shown separately from the coastal land areas. Figures 4 and 5 show by years the number of crew-months of seismic and gravity work done offshore Louisiana and offshore Texas. Although some geophysics exploration work had been done in limited areas of the gulf earlier, the intensive campaign of exploration by the industry did not begin until 1944. Activity increased rapidly, reaching a peak in the years 1947 and 1948, then began declining following a U. S. Supreme Court decision which held that the federal Government had *paramount rights* over the offshore water covered areas. Offshore exploratory work remained at a low level during the years 1950, 1951 and

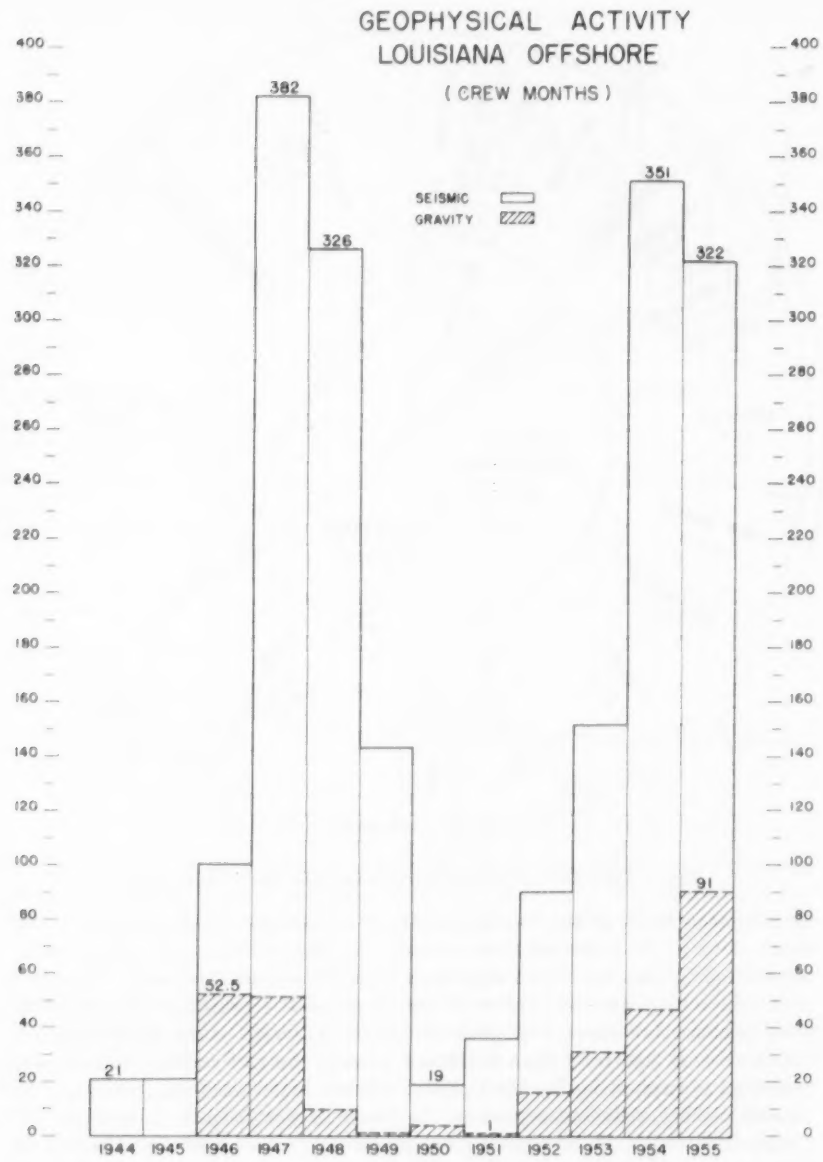

FIG. 4. Seismograph and gravimeter crew-months by years in the Louisiana portion of the Gulf of Mexico.

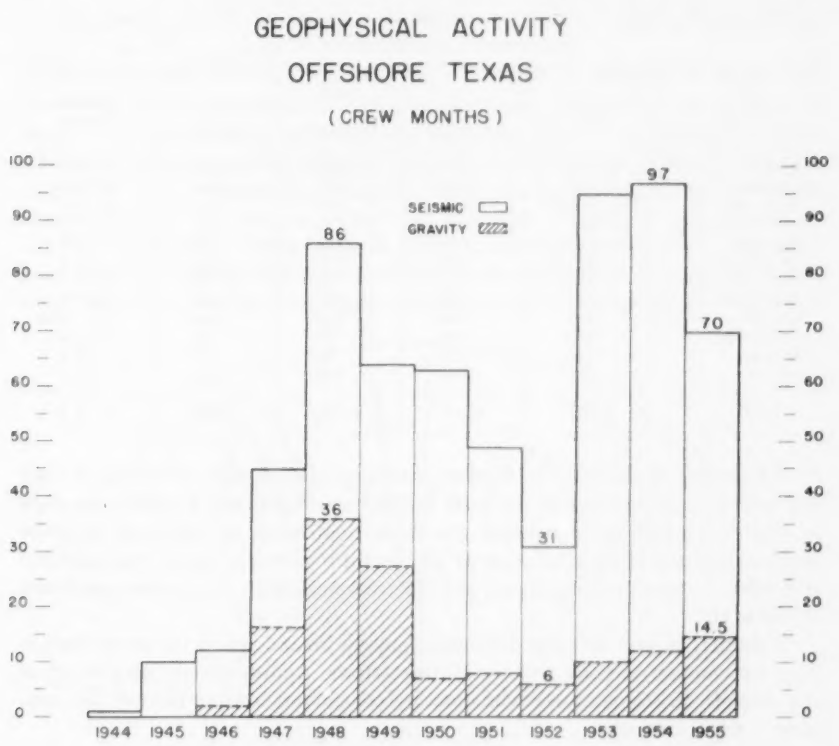

FIG. 5. Seismograph and gravimeter crew-months by years in the Texas portion of the Gulf of Mexico.

1952. Following the attempt by the U. S. Congress to fix the boundaries between federal and state owned water covered areas by passage of the Outer Continental Shelf Lands Act (Tidelands Act) in August 1953, there was an immediate upsurge in geophysical operations in the Gulf of Mexico. Seismic work continued at a relatively high level throughout 1955 in both the Louisiana and Texas offshore areas, although the activity was less in both areas than in 1954. Gravity work in the Gulf of Mexico reached an all time high of 105 crew-months in 1955, the major portion of the work being done off the Louisiana coast.

As shown in Figure 3, seismograph operations increased in the land areas of coastal Texas and coastal Louisiana. Seismic work continued at a high rate in the Rocky Mountain states in 1955 accounting for slightly more than one quarter (26.7 percent) of the total U. S. effort. An increase was reported in Wyoming; Colorado remained about even, while Montana, New Mexico, North Dakota and other states had decreases in activity. The Mid-Continent region, accounting

TABLE II

SEISMOGRAPH CREW-MONTHS IN U. S.

State	1954	1955			Percent Change
		Company	Contract	Total	
Texas	2,107	986	1,478	2,464	+16.9
Louisiana	1,303	262	1,280	1,542	+18.3
Wyoming	535	287	292	579	+ 8.2
New Mexico	465	257	164	421	− 9.5
Montana	456	149	213	362	−20.6
Oklahoma	441	192	202	394	−10.7
North Dakota	284	72	62	134	−52.8
Mississippi	233	157	164	321	+37.7
Colorado	228	100	129	229	+ .004
California	180	84	88	172	− 4.4
Kansas	136	71	87	158	+16.2
Others	495	174	140	314	−16.0
Total	6,863	2,791	4,299	7,090	+ 3.3

for 8.8 percent of the total U. S. effort, had increased seismic operations in 1955 due mainly to an increase in the work in the state of Kansas. A notable increase in seismic activity in Mississippi was more than offset by decreases in other southeastern states. A tabulation of seismograph crew-months in the principal states for the years 1954 and 1955 and the corresponding rate changes are shown in Table II.

Table II, as well as Table III below, gives a breakdown of the work done in 1955 by company owned and by contract crews. Approximately 60 percent of the total U. S. seismic work was done by contractors and 40 percent by company owned crews.

TABLE III

GRAVITY CREW-MONTHS IN U. S.

State	1954	1955			Percent Change
		Company	Contract	Total	
Texas	439	225	180	405	− 7.7
Louisiana	183	63	119	182	− 0.5
New Mexico	39	32	75	107	+174.3
Nevada	80	5	53	58	− 27.5
California	48	16	29	45	− 6.3
Mississippi	39	19	11	30	− 23.1
Wyoming	57	12	40	52	− 8.7
Colora	15	6	32	38	+153.3
Montana	28	19	30	49	+ 75
Washington	—	—	4	4	*
Oregon	—	12	5	17	*
Others	69	10	77	87	+ 26.1
Total	997	419	655	1,074	+ 7.7

* States not listed separately in 1954.

The geographic distribution of gravimeter work in the United States during 1955 is shown in Figure 6.

Gravity exploration work during 1955 declined in all parts of Texas and Louisiana but these states still accounted for more than half of the total work done in the nation. Activity in the two states amounted to 54.6 percent of the total U. S. effort in 1955 as compared to 62.5 percent in 1954. A marked increase in gravity work occurred in the Rocky Mountain region where approximately one-third of the nation's total effort was expended. Notable increases were reported in Montana, Colorado, New Mexico and other states, while decreases were noted in Nevada and Wyoming. The combined Pacific Coast states had a small increase in activity, although a slight decline was reported in California.

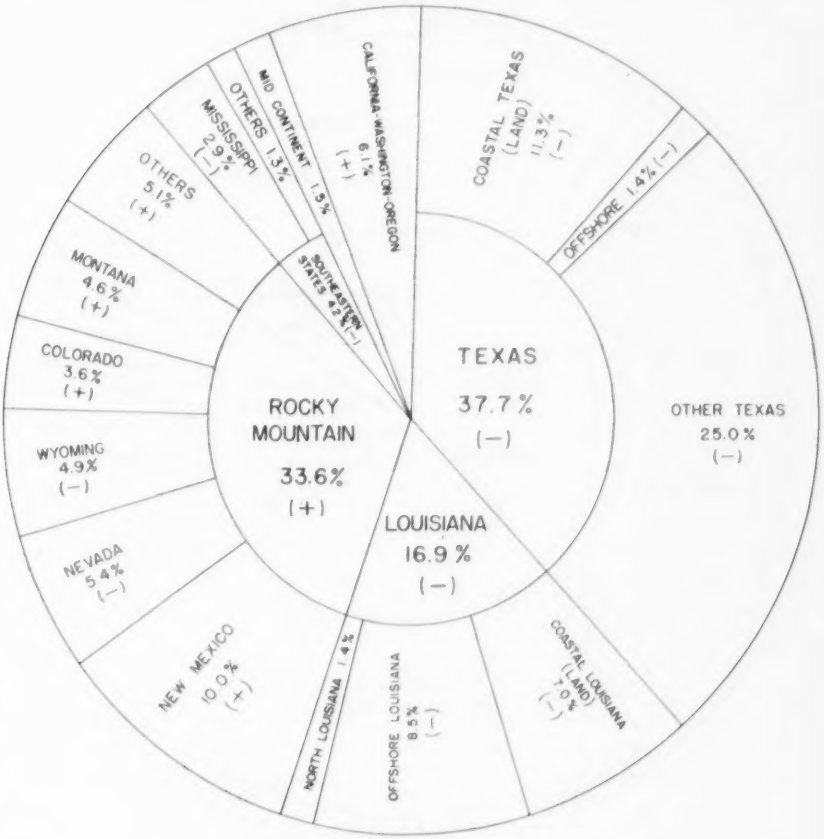

FIG. 6. Distribution of gravimeter prospecting in the U.S.A. in 1955.

Table III shows a list of the gravity crew-months in the more active states for both 1954 and 1955. A breakdown of the reported crew-months in 1955 by company owned and contract crews reveals that 61 percent of the gravity work in the United States was done by contractors and 39 percent by company owned crews.

The distribution of the world's exploratory effort by the seismic method in 1955 is shown in Figure 7. As in past years the greatest concentration of seismic work was in the North American continent, but due to stepped up operations in other parts of the world the percentage participation in the world total effort was less than in 1954, 79.8 percent in 1955 and 83.2 percent in 1954. Significant relative increases were reported in South America, Europe and Africa. The

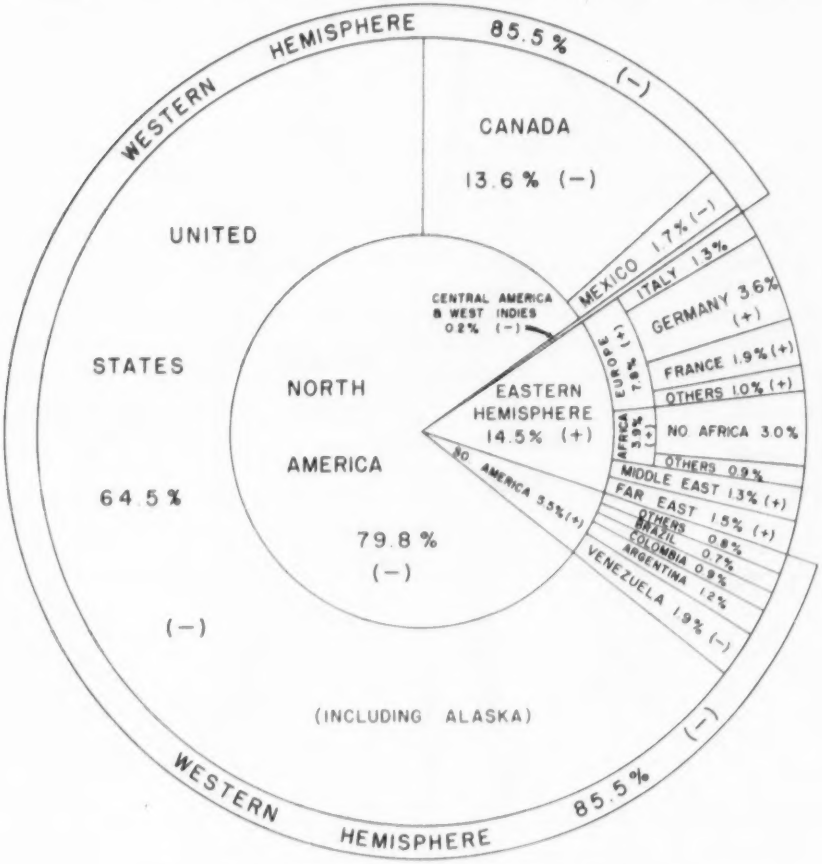

FIG. 7. World distribution of seismograph prospecting in 1955.

countries of South America where greatest activity was reported are: Argentina, Brazil, Colombia, Peru and Venezuela. The countries of France, Germany and Italy accounted for 87.1 percent of European seismic work during 1955. Scenes of important seismic activity in Africa during the year were: Algeria, Angola, Egypt, French Equatorial Africa, Madagascar, Nigeria and Tunisia. The countries accounting for the major portion of the seismic exploration in the Middle East and Far East are: Iraq, West Pakistan, India, Indonesia, Australia and Japan.

The world distribution of gravimeter operations during 1955 is shown in Figure 8. The major portion of the world's total gravity exploration effort con-

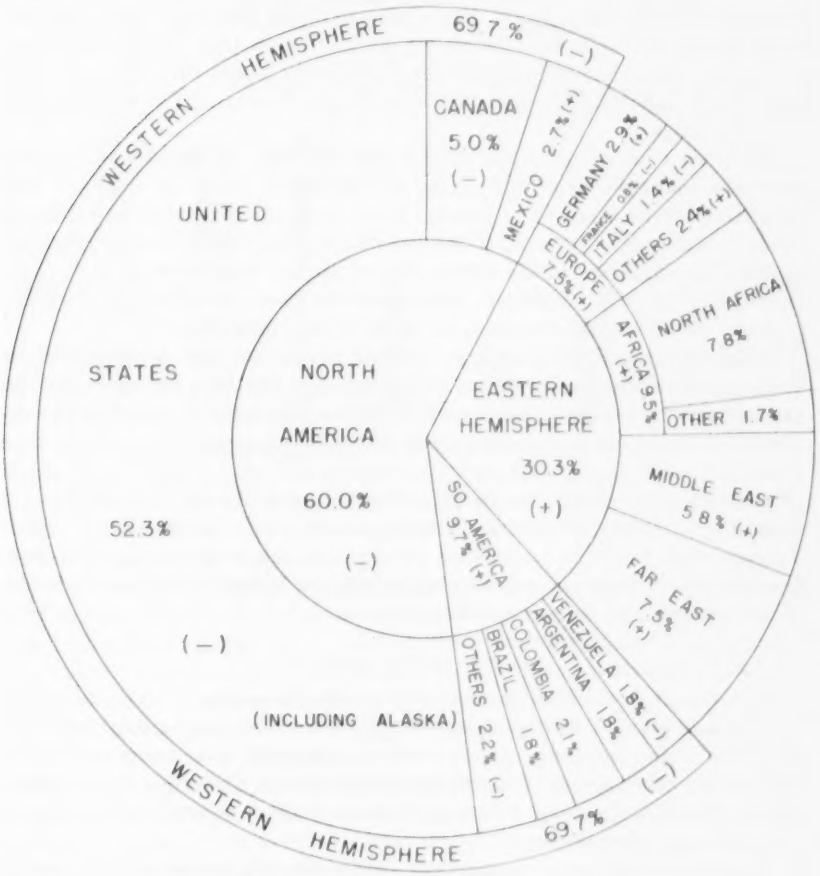

FIG. 8. World distribution of gravimeter prospecting in 1955.

tinues to be concentrated in the western hemisphere. Increased activity, measured in crew-months, was reported in South America and in the countries of North America, with the exception of Canada where a slight decrease was reported, but the proportion of the world's total gravity work done in these areas (69.7 percent) was smaller in 1955 than in the previous year, (78.5 percent). The reduced percentage participation in the world total by the countries of the western hemisphere is due to significant increases in activity in the countries of the eastern hemisphere, particularly during the second half of 1955. Gravity prospecting was reported in Algeria, Cameroun (Fr.), Egypt, French Equatorial Africa, French West Africa, Kenya, Madagascar, Taganyika and Tunisia on the continent of Africa. In the Middle East gravimeter operations were conducted in Turkey, Iraq, Israel, East Pakistan, West Pakistan, India, Yemen, Saudi Arabia, Qatar and in the waters of the Persian Gulf. In the Far East, where the level of gravity explorations was slightly higher than in 1954, work was done in Indonesia, Netherlands New Guinea, Australia, Papua, New Zealand and Japan.

As in past years, statistical information on magnetic explorations by the petroleum industry during 1955 is incomplete. Better means of acquiring and presenting the data are being sought. The information available, as shown in Table I, indicates a reversal of the downward trend in world-wide magnetic explorations suggested in the interim report for the first six months of 1955. Decreased activity in the western hemisphere was more than offset by significant increases in the work in the countries of the eastern hemisphere.

Since the meager cost data on geophysical exploration work is inadequate for anything more than rough estimates, no attempt will be made to report the expenditures by the petroleum industry. With a high level of activity and with increased unit costs, it is evident that the total expenditure for geophysical investigations was higher in 1955 than in recent past years. Estimates of capital investment in geophysical exploration for petroleum during 1955 which were made by Dr. Sigmund Hammer at mid-year appear to be reasonably correct. The predicted range for world-wide geophysical investment in 1955 was from $350,000,000 to $400,000,000. Expenditures in the United States were expected to be between $200,000,000 and $250,000,000.

II. THE MINING INDUSTRY

The employment of geophysical methods by the mining industry continued to increase during 1955. An average of 585 professional geophysicists were employed in mining exploration during 1955 as compared to an average of 573 in 1954. Total expenditures in mining geophysics rose to a record high of approximately $7,100,000 in 1955. This is an increase of about one million dollars over the total 1954 expenditures.

Increases in the use of geophysical methods by the mining industry during 1955 took place in Canada, Europe and the Mediterranean area, Australia and

South America. Decreases were reported in the United States and in the countries of Africa and Asia. Canada still leads with the highest expenditures for mining geophysics (40.1 percent of the world's total) and with the largest number of professional geophysicists employed (26.8 percent of the total). Although the activity in the United States decreased in 1955 as compared to the previous year, the U. S. still accounted for 22.2 percent of the world's professional manpower employed and 20.2 percent of the global expenditures. Europe and the

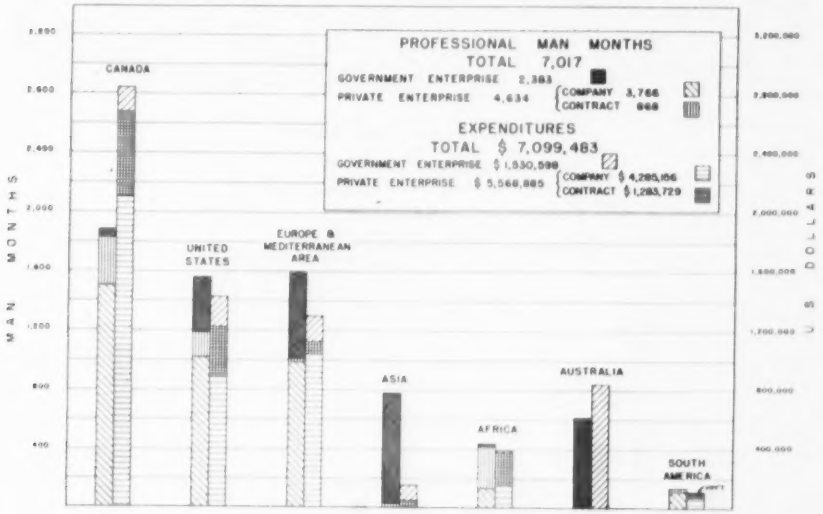

FIG. 9. Mining geophysics—World-wide effort in 1955 by areas.

Mediterranean area ranked second in the utilization of professional geophysicists, with 22.7 percent of the world's total man-months, and third in expenditures (18.3 percent of the total).

World-wide activity in mining geophysics in 1955 is shown by areas in Figure 9. In Figure 9, as well as in Figure 10 to follow, two measures of activity are presented. In the left hand columns under each major area the number of professional man-months utilized is plotted. The adjoining columns on the right show the expenditures converted to U. S. dollars. The different patterns of cross-hatching in the columns are used to show a breakdown of the mining geophysical effort by government enterprise and by private enterprise, with the private enterprise portion being further subdivided according to company owned and contract crews. Government agencies continue to sponsor and finance a considerable portion of the world's mining geophysics. Governmental participation in 1955 amounted to 34 percent of the total manpower utilized and 22 per cent of the total expenditures. Private enterprise accounted for 66 percent of employ-

ment and 78 percent of expenditures. In mining exploration by private enterprise company owned operations accounted for the major share of the activity, 81 percent of the man-months and 77 percent of expenditures. Operations conducted by contractors for private enterprise in the mining industry accounted for 19 percent of the man-months and 23 percent of the expenditures.

The activity in mining geophysics during 1955 according to methods is shown in Figure 10. The ground magnetic work reported by the mining industry in 1955 increased over that reported in 1954, the increases being 6.9 percent in manpower utilized and 13.6 percent in expenditures. Explorations by the aerial magnetometer declined in 1955 compared to the previous year. Due to the nature of the work, comparatively few professional people are

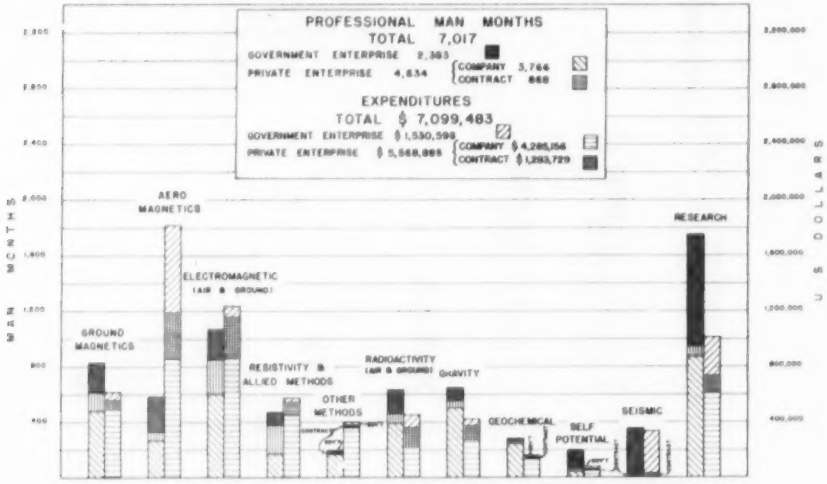

FIG. 10. Mining geophysics—World-wide effort in 1955 by methods.

employed in aeromagnetic exploration in relation to the expenditures involved. Only 8.3 percent of the professional personnel in mining geophysics engaged in aeromagnetic work, while the cost of the work reported amounted to 25.6 percent of the total expenditures by the industry. Measured in manpower utilization, electromagnetic operations (airborne and ground) were at about the same level in 1955 as in 1954; however, expenditures for electro-magnetic work more than doubled in 1955. Arranged in the order of decreasing expenditures, the various geophysical methods employed by the mining industry during 1955 ranked as follows: 1) aeromagnetic, 2) electro-magnetic (airborne and ground), 3) ground magnetic, 4) resistivity and allied electrical methods, 5) radioactivity (airborne and ground), 6) gravity, 7) miscellaneous methods, mainly Telluric, 8) seismic, 9) geochemical, 10) self-potential. Decreases in expenditures were noted in

aeromagnetic, geochemical, self-potential and seismic explorations in 1955, while expenditures for all other types of geophysical work increased.

Research in the applications of all types of geophysical methods to mining exploration problems rose to a new record high in 1955. Manpower utilization in research increased 2.1 percent over 1954, while expenditures increased 16.7 percent, reaching an amount in excess of one million U. S. dollars.

It seems reasonable to expect there will be further increases in the employment of geophysical methods in mining exploration in the future. More intensive use of geophysics in the areas now under investigation, as well as more widespread use as new areas of the world are opened to exploration, is in prospect.

GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 104-119, 10 FIGS.

GEOPHYSICAL ACTIVITY IN 1956 INTERIM REPORT TO MID-YEAR*

HOMER G. PATRICK†

I. THE PETROLEUM INDUSTRY

World-wide activity[1] in geophysical explorations by the petroleum industry, after reaching a record high in 1955, declined by approximately 2 percent in the first six months of 1956. An average of 1098 geophysical crews of all types were employed in the first half of 1956 compared to the 1955 average of 1119 crews. The decline in global activity can be attributed to reductions in the use of the three principal geophysics methods, seismic, gravity and magnetic in the western hemisphere. Increased use of all methods, except magnetic which showed a small decline, was reported in the eastern hemisphere.

World-wide distribution of geophysical activities by area and by method, and rate comparisons with statistics for 1955 are shown in Table I. On a global basis seismic work declined 1.2 percent during the first half of 1956, gravity work was down 7.6 percent and magnetic work was down 6.6 percent. Although accounting for a small part of the total effort, explorations by other methods, mainly electrical, increased to a large degree in percentage. Total geophysical activity in the United States decreased 5.6 percent in the first six months of 1956; Canadian explorations showed a 2.6 percent decline; and activity in the entire western hemisphere was down 3.7 percent.

Figure 1 shows the world distribution of seismograph prospecting during the first half of 1956. The percentage figures shown in the divisions and subdivisions of the chart represent the percent of the world's total seismic work. The (+) and (−) signs in this chart, as well as in the charts to follow, indicate increases and decreases in relative concentration of geophysical activity in the first half of 1956 as compared to the year 1955. The greatest concentration of exploratory effort by the seismic method continues to be in North America. With the trend toward more geophysical activity in other parts of the world, the North American participation in the world's seismic effort has declined steadily from 86.9 percent in 1951 to 78.8 percent in the first part of 1956. Small relative increases were reported in Central America and the West Indies, in Mexico, and in Canada. The United States showed decreased participation in the global effort. Due to greater activity in Europe, Africa and the Middle East the proportion of the

* Report of the Standing Committee on Geophysical Activity of the Society of Exploration Geophysicists. The members of the committee are: Kenneth L. Cook, R. J. Copeland, Santos Figueroa Huerta, W. W. Hardy, Herbert Hoover, Jr., C. N. Hurry, Kumiji Iida, C. C. Lister, and Homer G. Patrick, Chairman.

† Humble Oil & Refining Company, Houston, Texas.

[1] Total geophysical activity covered in this report is known to be incomplete, as statistical data are not available from all countries of the world.

TABLE I

CREW-MONTHS OF GEOPHYSICAL EXPLORATION FOR PETROLEUM

	U.S.A.			Canada			Western Hemisphere			Eastern Hemisphere			World		
	1955 12 mo.	1956 6 mo.	Percent Change	1955 12 mo.	1956 6 mo.	Percent Change	1955 12 mo.	1956 6 mo.	Percent Change	1955 12 mo.	1956 6 mo.	Percent Change	1955 12 mo.	1956 6 mo.	Percent Change
Seismic	7,000	3,420	− 3.3	1,406	751	+ 4.0	9,395	4,590	− 2.3	1,589	836	+ 5.2	10,084	5,426	− 1.2
Gravity	1,074	440	−18.1	103	28	−45.6	1,431	021	− 13.2	621	327	+ 5.3	2,052	948	− 7.6
Magnetic	76	19	−50.0	—	—		146	65	− 10.9	173	84	− 2.9	319	140	− 6.6
Other	—	—		—	—		15	16	+113.3	60	50	+66.7	75	66	+76.0
Total	8,240	3,888	− 5.6	1,500	779	− 2.6	10,987	5,292	− 3.7	2,443	1,297	+ 6.2	13,430	6,589	− 1.9

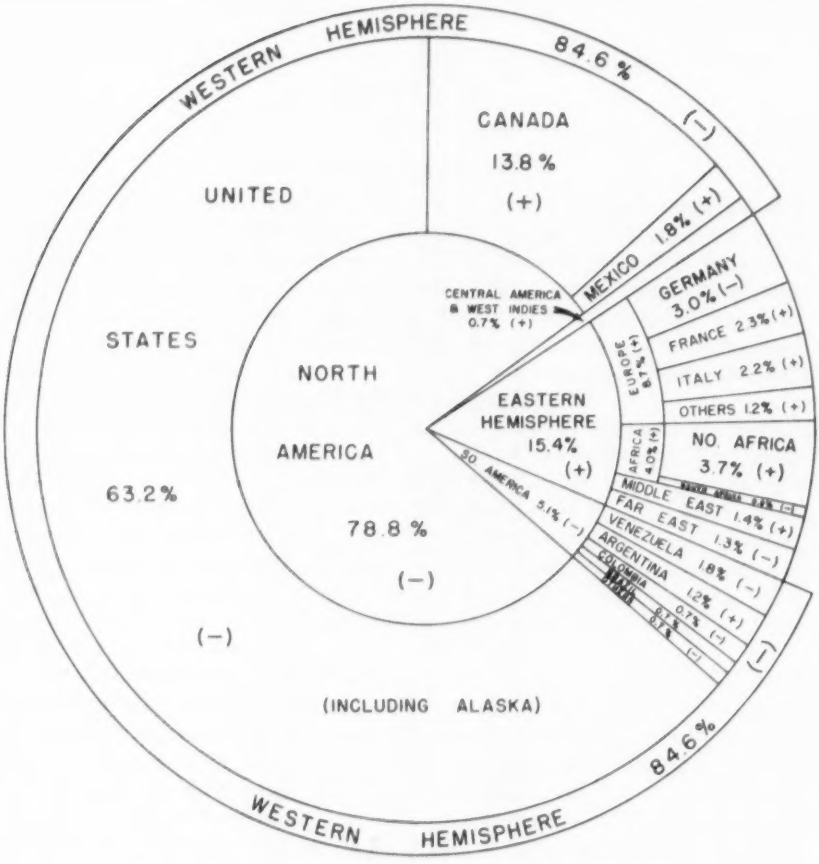

FIG. 1. World distribution of seismograph prospecting in 1956 (6 mo.).

world's seismic effort in the eastern hemisphere rose from 14.5 percent in 1955 to 15.4 percent in the first half of 1956.

The world distribution of gravity explorations in the first six months of 1956 is shown in Figure 2. Although the western hemisphere continues to dominate the chart, its percentage participation in the world's total gravity exploration work dropped from 69.7 percent in 1955 to 65.5 percent during the first six months of 1956. This decline in the utilization of the gravity method in the western hemisphere occurred wholly within the United States and Canada. Gains in gravity activity were reported in South America and Central America, as well

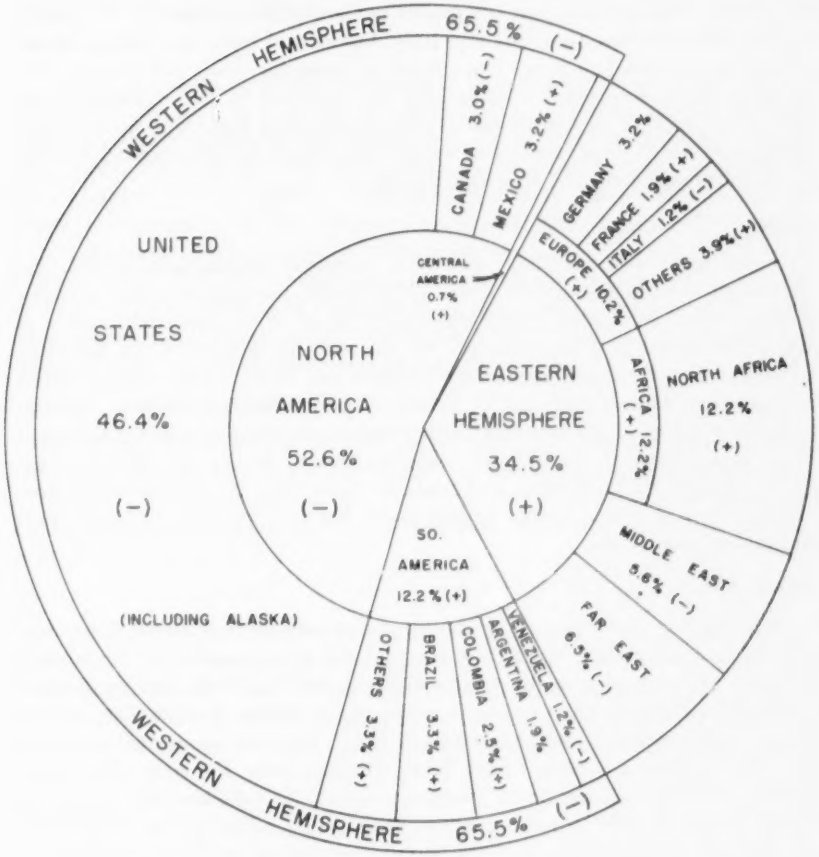

FIG. 2. World distribution of gravimeter prospecting in 1956 (6 mo.).

as in Mexico. The eastern hemisphere, as a whole, showed increased gravity activity with gains taking place in Europe and Africa while slight declines occurred in the Middle East and Far East.

EASTERN HEMISPHERE

Europe

An average of 78 seismic crews, 16 gravity crews and 2 magnetic crews operated in Europe during the first half of 1956. Geophysics contractors did 80 percent of the seismic work and 88 percent of the gravity work during the

period. As in the previous year the greater portion of the geophysical activity in Europe was in France, Germany and Italy. France and Italy reported increased activity as compared to 1955. The number of crews increased in Germany, but the total effort measured in crew-months was restricted by an unusually severe winter. At midyear 19 seismic crews were operating in Italy and Sicily. Other countries in which some geophysical work was done are: Austria, Greece, Netherlands, Portugal, Spain and United Kingdom.

Africa

Total geophysics operations in Africa increased substantially in the first six months of 1956. Seismic work was about double the 1955 rate while gravity work increased by approximately 25 percent. Much of the reported increase in activity occurred in French Africa. An accurate breakdown of the available statistical data between French North Africa and French West Africa cannot be made, but the two combined accounted for more than two-thirds of the total exploratory effort on the continent. Other African countries in which geophysical work was conducted are: Angola, Belgian Congo, British Somaliland, East Africa, Egypt, Libya, Nigeria and Somalia. More than 90 percent of the geophysical work in Africa during the first half of the year was done by geophysical contracting companies.

Middle East

Exploratory operations by geophysical methods in the Middle East were slightly increased in the first half of the year due to a spreading of the activity into new areas. Increasing activity in explorations of all types are reported in Turkey, for example, and some work is now being done in Jordan. The greatest concentration of geophysical effort was in Israel, Iraq and Saudi Arabia. Scenes of other significant activity were: Aden, Dhofar, Iran, Kamaran (Red Sea), Kuwait, Persian Gulf and Qatar. Company owned crews did less than 10 percent of the work in the Middle East countries, the majority being done by contractors.

Far East

According to the statistical data available, geophysical activities in the Far East dropped during the first six months of 1956. There is reason to believe, however, the information from Australia, India, East Pakistan and West Pakistan may be incomplete, although some work in each of these areas was reported. It is believed there were some operations in Burma, but no data were received from that country. Australia, Netherlands New Guinea, West Pakistan, India and Papua were the scenes of greatest activity in the Far East. Other areas in which petroleum explorations were reported are: Indonesia, New Zealand, East Pakistan, Japan and the Philippines. Approximately 85 percent of the total geophysical work in the Far East was done by contractors.

WESTERN HEMISPHERE

South America

Total activity in geophysics exploration in the countries of South America during the first half of 1956 was at about the same level as in 1955. A slight decline in seismic work was offset by a gain in gravity work. A significant amount of magnetic work was reported during the period. Venezuela, with an average of 45 seismic crews and 20 gravity crews, continues to lead in geophysics exploration for petroleum. Activity continues high in Argentina, Brazil and Colombia. Other countries in which geophysical operations were conducted are: Bolivia, Chile, Peru and Uruguay. A small amount of seismic work was done on the Island of Trinidad. A breakdown of the total geophysics operations in South America by company owned and contract crews reveals that 58 percent of the work was done by company owned crews and 42 percent by contract crews.

Central America and the West Indies

More geophysical activity in the Central American countries seems to be in prospect, but very little was reported during the first part of 1956. Seismic and gravity explorations were conducted in Cuba, and a small amount of seismic work was done in Jamaica and in the Bahamas. All of the work reported was done by contractors.

Mexico

Total geophysical effort by the petroleum industry in Mexico during the first six months of the year amounted to 98 crew-months seismic work and 30 crew-months gravity work. No other methods of geophysical prospecting were utilized. Crews of contracting companies did 80 percent of the seismic work and 60 percent of the gravity work, the remainder being done by company owned crews.

Canada

Monthly variations in seismograph and gravimeter crew-months in Canada during the past nine and one-half years are shown in Figure 3. As shown by the chart a 10 percent decline in seismic activity occurred at the beginning of the year and a much sharper drop occurred in April. The number of crews in operation in Canada decreased from 164 at the end of 1955 to 149 in January 1956 and to 89 in April, a new low for recent years. Some recovery is indicated as the number of crews increased to 109 in May. During the first quarter of the year an average of 149 seismic crews were active. During the second three months of the period the average was 102 crews. In western Canada, where most of the effort was concentrated, gravity explorations decreased from 102 crew-months in 1955 to 28 crew-months in the first half of 1956, a decrease in annual rate of 45 percent. A small amount of gravity and magnetic work, which is not included

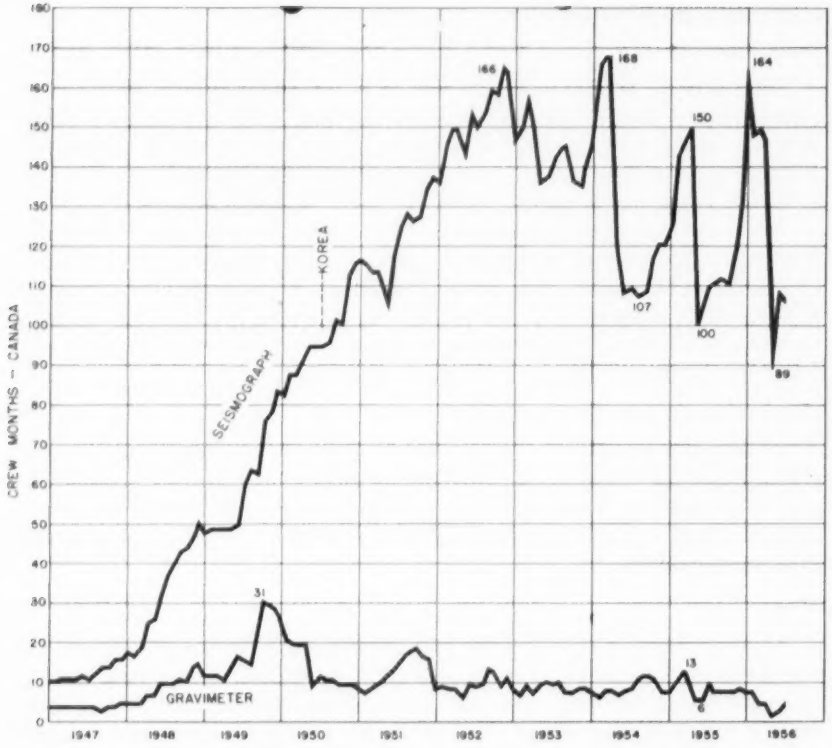

FIG. 3. Monthly variations in seismograph and gravimeter crew-months in Canada.

in the statistical data shown in Table I, was done in the provinces of Ontario, Quebec and the Maritimes in eastern Canada.

The major portion of the geophysical activity in Canada was in the province of Alberta where 530 crew-months of seismic work and 22 crew-months gravity work were reported for the period January-June 1956. British Columbia was second with 106 crew-months seismic work and 3 crew-months gravity work. Saskatchewan with 99 crew-months seismic work and 3 crew-months gravity work ranked third. The remainder of the geophysical exploration work in the western provinces consisted of 16 crew-months seismic work in Northwest Territories and Manitoba. Approximately 80 percent of all Canadian geophysical work during the first half of the year was done by contractors.

United States

Monthly variations in seismograph and gravimeter crew-months in the United States since the year 1944 are shown in Figure 4. Some curtailment in

both seismic and gravity prospecting was noted in the first quarter of 1956. Part of the loss was regained during the second quarter of the year. An average of 571 seismic crews operated in the United States during the first half of 1956, compared to the 1955 average of 591 crews. Gravity operations were reduced by 18.1 percent in comparison to the previous year. The number of gravity crews in operation averaged 73 in the first half of 1956 compared to an average of 90 crews in 1955.

The geographic distribution of seismograph prospecting in the United States in the first six months of 1956 is shown in Figure 5. Although significant changes took place in a few states, notably New Mexico, the distribution of the seismic exploratory effort remained approximately as it was in 1955. Slight decreases were reported in the Rocky Mountain and Mid-Continent areas and in the state of Texas. Corresponding increases were reported in California and Louisiana and in the Southeastern states. In the Rocky Mountain area gains in seismic

FIG. 4. Monthly variations in seismograph and gravimeter crew-months in the U.S.A.

activity in New Mexico and Utah were more than offset by decreases in Colorado, Montana, North Dakota and Wyoming. Seismic work continued to increase in Mississippi during the first half of the year. Very little activity was reported in the other Southeastern states. Activity was reduced in Oklahoma and Kansas where the major portion of the Mid-Continent seismic work was concentrated. The states of Texas and Louisiana combined accounted for 56.4 percent of all seismic work in the United States during the period, compared to 56.5 percent in 1955. Louisiana had an increase in activity, particularly in the coastal area, while activity in coastal Texas declined, suggesting that a number of crews were shifted from coastal Texas to coastal Louisiana. A tabulation of seismograph crew-months in the more active states for the year 1955 and the first half

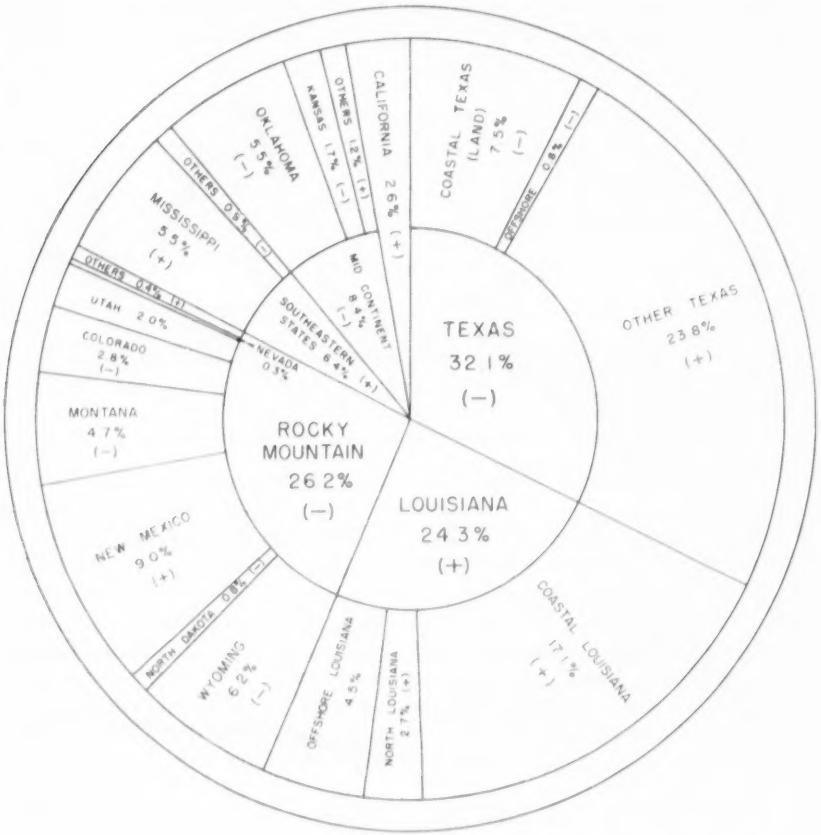

FIG. 5. Distribution of seismograph prospecting in the U.S.A. in 1956 (6 mo.).

of 1956, showing a breakdown by company owned and contract crews, as well as the corresponding rate changes, is given in Table II. Approximately 55 percent of the U. S. seismic work reported during the first half of the year was done by contractors and 45 percent by company owned crews. The ratio was 60–40 in favor of the contracting companies in 1955.

The distribution of gravimeter prospecting in the United States in the first six months of 1956 is shown in Figure 6. The Rocky Mountain area was the only major portion of the United States to show a substantial increase in gravity explorations during the first six months of the year. This increase was due entirely to the stepped-up gravity surveys conducted in the states of New Mexico, Montana and Utah. A moderate increase occurred in the Mid-Continent states

TABLE II

SEISMOGRAPH CREW-MONTHS IN U. S.

State	1955			1956 First Six Months			Percent Change
	Company	Contract	Total	Company	Contract	Total	
Texas	986	1,478	2,464	506	593	1,099	−10.8
Louisiana	262	1,280	1,542	275	559	834	+ 8.2
Wyoming	287	292	579	115	98	213	−26.4
New Mexico	257	164	421	142	167	309	+46.8
Montana	149	213	362	67	93	160	−11.6
Oklahoma	192	202	394	79	109	188	− 0.5
North Dakota	72	62	134	11	14	25	−62.7
Mississippi	157	164	321	79	108	187	+16.5
Colorado	100	129	229	45	56	101	−11.8
California	84	88	172	22	68	90	+ 4.6
Kansas	71	87	158	22	36	58	−26.6
Utah	*	*	*	33	35	68	*
Others	174	140	314	44	53	97	−38.2
Total	2,791	4,299	7,090	1,440	1,989	3,429	− 3.3

* State not listed separately in 1955 report.

but this area accounts for a very small part of the total U. S. gravity effort. Significant decreases in gravity work were reported in Texas and Louisiana. Gravity activity in the two states amounted to 48.0 percent of the total U. S. effort in the first half of 1956, 54.6 per cent in 1955 and 62.5 percent in 1954.

A tabulation of gravity crew-months in the principal states for the first half of 1956 and the year 1955 and the corresponding rate changes are shown in Table III. A breakdown of the reported crew-months by company owned and contract crews is also shown. Contract crews did 58 percent of the total U. S. gravity work in the first half of 1956 compared to 61 percent done by contractors in 1955.

Figure 7 shows the number of seismograph and gravimeter crew-months by years in the Louisiana portion of the Gulf of Mexico. Figure 8 shows a similar chart for the Texas portion of the Gulf of Mexico. Seismic work was carried on

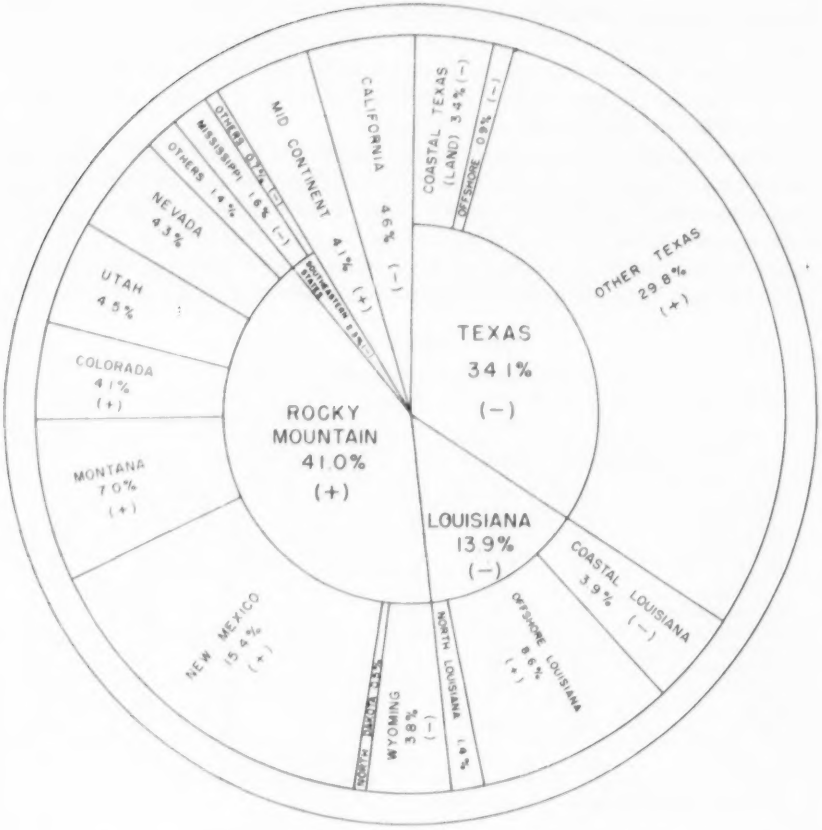

FIG. 6. Distribution of gravimeter prospecting in the U.S.A. in 1956 (6 mo.).

in the Louisiana offshore area at about the 1955 rate for the first four or five months of the year, much of it in preparation for a sale of leases announced by the U. S. Department of Interior. Seismic work in the Texas portion of the Gulf of Mexico was below the 1955 level during that period. The offshore lease sale was cancelled in May 1956 pending settlement of the boundary dispute between the state of Louisiana and the Federal government. Following this action seismic work in the Gulf fell off rapidly. Only 21 crews were engaged in seismic work in the offshore area of the two states at midyear compared to 39 crews in Janaury. Gravity work in the Gulf of Mexico during the first half of the year showed a decline from the record high of 105 crew-months in 1955. As in seismic work, it is

TABLE III

GRAVITY CREW-MONTHS IN U. S.

State	1955			1956 First Six Months			Percent Change
	Company	Contract	Total	Company	Contract	Total	
Texas	225	180	405	66	84	150	−25.9
Louisiana	63	119	182	33	28	61	−33.0
New Mexico	32	75	107	33	35	68	+27.1
Nevada	5	53	58	—	20	20	−31.0
California	16	29	45	8	6	14	−37.8
Mississippi	19	11	30	4	3	7	−53.3
Wyoming	12	40	52	—	17	17	−34.6
Colorado	6	32	38	—	18	18	− 5.3
Montana	19	30	49	18	13	31	+26.5
Washington	—	4	4	—	—	—	—
Oregon	12	5	17	6	—	6	−29.4
Utah	*	*	*	5	15	20	*
Others	10	77	87	9	19	28	−35.6
Total	419	655	1,074	182	258	440	−18.1

* State not listed separately in 1955 report.

expected that gravity operations will be considerably reduced during the second half of the year.

II. THE MINING INDUSTRY

Continued increases in the use of geophysical methods by the mining industry were reported during the first six months of 1956. Expenditures, converted to U. S. dollars, as well as professional man-months utilized are presented as measures of geophysical activity in the mining industry. Total expenditures in mining geophysics for the first half of the year were at an annual rate of $11,200,000 compared to $7,100,000 for the year 1955, an indicated increase of 58 percent. The average number of professional geophysicists employed in mining exploration increased approximately 10 percent from 585 in 1955 to 644 in the first half of 1956. Greater use of methods in which man-power is not a predominant factor accounts for the larger increase in expenditures compared to the increase in employment of professional man-power.

World-wide activity in mining geophysics in the first half of 1956 is shown in Figure 9. The bars at the left under each major area show the professional man-months utilized, while the adjoining bars on the right show the expenditures in U. S. dollars. The portion of the mining geophysical effort done by government enterprise is shown in Figure 9, and in Figure 10 to follow, by slanted cross-hatching. That part done by private enterprise is further subdivided according to company owned crews (shown in solid form) and contract crews (shown in vertical cross-hatching). Increased rates of expenditures in comparison to 1955 were reported in all major areas except Europe and Asia. Significant increases in man-power utilization took place in all of the areas, except Canada and Aus-

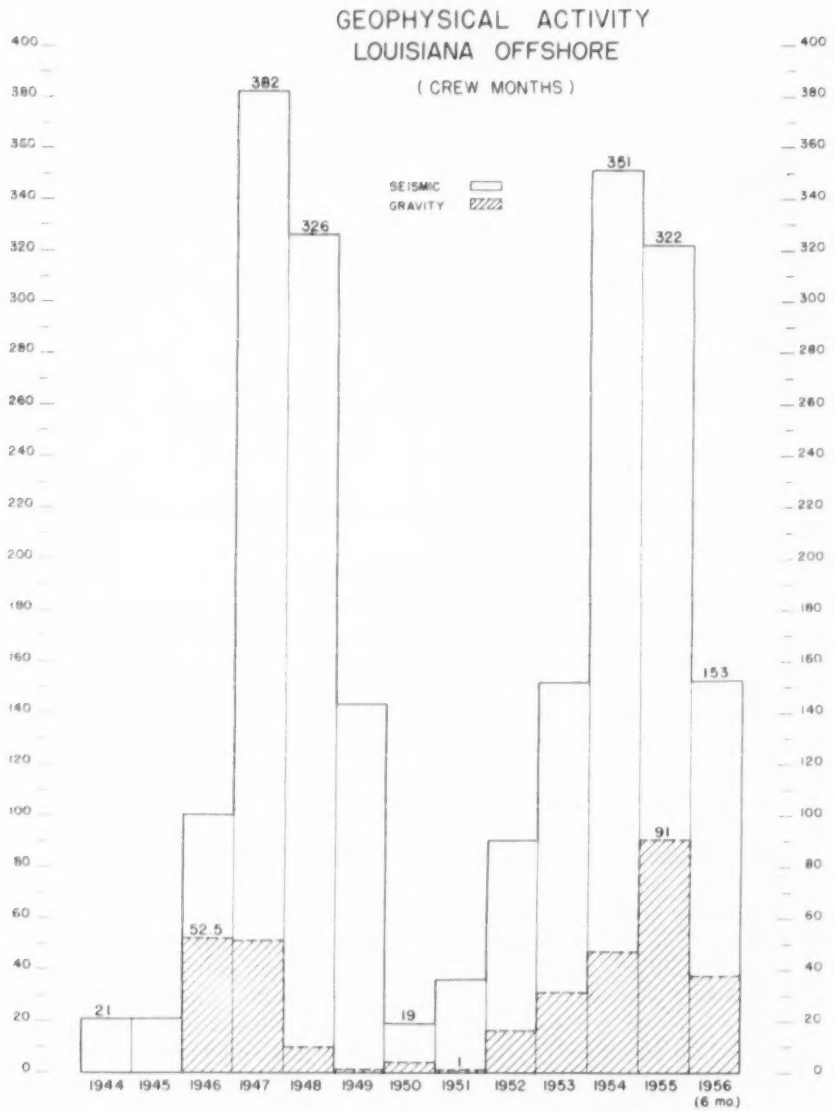

FIG. 7. Seismograph and gravimeter crew-months by years in the Louisiana portion of the Gulf of Mexico.

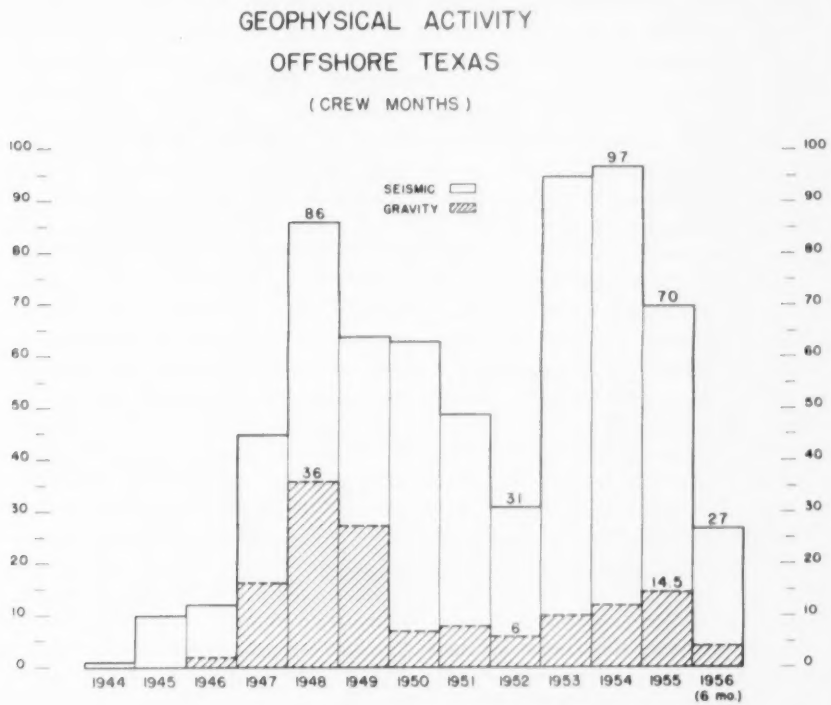

FIG. 8. Seismograph and gravimeter crew-months by years in the Texas portion of the Gulf of Mexico.

tralia, where slight decreases were reported, and Asia, where a large decrease occurred. Canada ranks first in total expenditures for mining geophysics in the first six months of 1956 (30.2 percent of the world's total), and third in manpower utilization (23.6 percent of the world's total). With expenditures about double the 1955 rate and with the number of professional geophysicists employed up by 43 percent, the United States ranks second among the major areas of the world in expenditures and first in employment of professional geophysicists. In terms of professional man-months utilized the major areas of the world ranked in decreasing order as follows: (1) United States, (2) Europe, (3) Canada, (4) Africa, (5) Australia, (6) South America, (7) Asia. In order of decreasing expenditures the various areas ranked as follows: (1) Canada, (2) United States, (3) Africa, (4) Australia, (5) Europe, (6) South America, (7) Asia. The United States, Africa and South America showed the greatest percentage increases in activity as compared to 1955 in both professional man-months and expenditures. The greatest percentage decrease in both categories occurred in Asia.

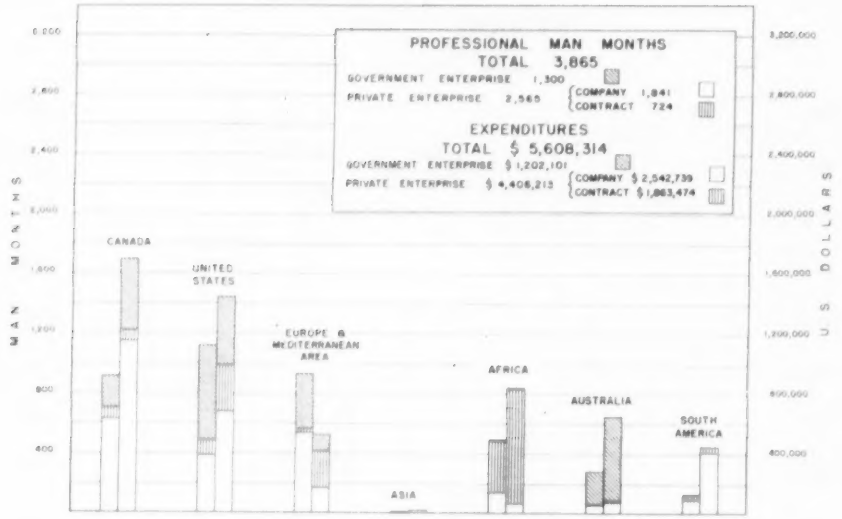

FIG. 9. Mining geophysics—World-wide effort in 1956 (6 mo.) by areas.

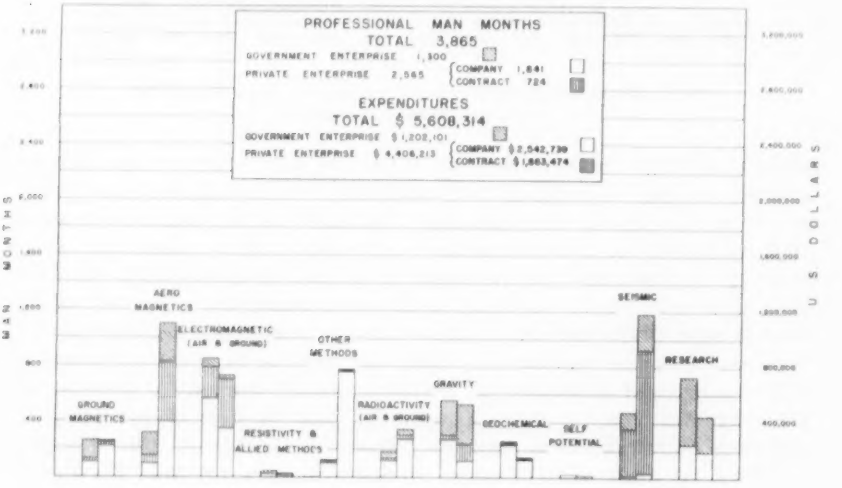

FIG. 10. Mining geophysics—World-wide effort in 1956 (6 mo.) by methods.

The activity in mining geophysics in the first six months of 1956 according to methods is shown in Figure 10. In recent months the seismic and gravity methods, long favored in petroleum explorations, have come into greater and more wide-spread use by the mining industry. Total expenditures for seismic work in the first half of 1956 reached an all time high and are at an annual rate more than six times that of the previous year. Professional manpower utilization in seismic explorations almost tripled in the six months period. Activity in gravity explorations measured in both manpower utilization and expenditures has increased twofold over 1955. Methods, in addition to seismic and gravity, which have had increased usage during the first half of 1956 are: aeromagnetic, electromagnetic, radioactivity, geochemical, and miscellaneous methods. Decreased activity was reported in ground magnetic, resistivity and self-potential methods.

Arranged in the order of decreasing expenditures, the various geophysical methods employed by the mining industry during the first six months of 1956 ranked as follows: (1) seismic, (2) aeromagnetic, (3) miscellaneous methods, mainly Telluric, (4) electromagnetic, (5) gravity, (6) radioactivity (airborne and ground), (7) ground magnetic, (8) geochemical, (9) resistivity and allied electrical methods, (10) self-potential. In the order of decreasing manpower utilization the methods ranked as follows: (1) electromagnetic, (2) gravity, (3) seismic, (4) aeromagnetic, (5) ground magnetic, (6) geochemical, (7) radioactivity, (8) miscellaneous methods, mainly Telluric, (9) resistivity and allied electrical methods, (10) self-potential.

The portion of the world-wide effort in mining geophysics which was sponsored by government agencies was very near the same in the first half of 1956 as in the year 1955, (34 percent of the total manpower utilized and 21 percent of the total expenditures). Private enterprise accounted for 66 percent of the professional employment and 79 percent of the expenditures. In mining exploration by private enterprise, company owned operations still account for the major share of the activity; however, the portion of the work done by contractors is increasing. Operations conducted by contractors for private enterprise in the first half of 1956 accounted for 28 percent of the professional man-months and 30 percent of the expenditures while in 1955 the proportions were 19 percent of the professional man-months and 23% of the expenditures.

An active geophysical research program was carried out by the mining industry in the first half of 1956, but below the 1955 level in both manpower utilization and expenditures. The number of professional geophysicists engaged in mining exploration research declined from an average of 146 in 1955 to 125 in the first part of 1956. Expenditures for research work declined by 17.5 percent from slightly more than one million U. S. dollars in 1955 to an annual rate of approximately 900,000 dollars in the first half of 1956.

It is evident that the role of geophysics in explorations for minerals is becoming an increasingly important one. Further expansion in the employment of geophysical methods by the mining industry is expected.

GEOPHYSICS, VOL. XXII, NO. 1 (JANUARY, 1957), PP. 120–135.

INDEX OF WELLS SHOT FOR VELOCITY

(Fifth Supplement)

V. U. GAITHER

ABSTRACT

This is the fifth supplement to the original Index published in the October 1944 issue of GEOPHYSICS, the first supplement appearing in the October 1946 issue, the second in the January 1949 issue, the third in the January 1951 issue, a combination of the four separate lists was published in booklet form in 1953 and the fourth supplement appeared in the January 1956 issue of GEOPHYSICS. Information is listed on 759 velocity surveys, most of which were shot in the years 1955 and 1956. Corrections and additional information on 7 previously indexed surveys are tabulated.

INTRODUCTION

This is the fifth supplement to the original "Index of Wells Shot for Velocity," published in the October 1944 issue of GEOPHYSICS. Information on the surveys was assembled by soliciting the various oil companies, seismograph contracting companies, co-operative well velocity survey associations and individuals. The response to our solicitation was very gratifying, and for such splendid co-operation the editors of GEOPHYSICS and myself wish to express our sincere appreciation.

We realize that this supplement is incomplete in one respect—the nature or type of survey is not indicated. In future supplements, which we hope to publish at yearly intervals, we plan to add a column to our usual headings indicating the "Type of Survey," whether conventional, continuous velocity log, long interval, etc. We believe this additional information will enhance the usefulness of the Index.

The first portion of this supplement gives surveys shot since the 1956 supplement; also surveys not here-to-fore reported in any of the previous editions. In the latter portion, corrections and additional information on previously listed surveys are shown in italics.

It is expected that some errors in the index will be discovered by those who use it to any extent. It is requested that all such errors, which withstand careful checking, be reported to the Business Manager of the Society and, likewise, information that is at present lacking on listed wells.

The writer is grateful to Miss Phyllis Faken for her assistance in cross-checking, reconciling and assembling information for this supplement.

NOTE: Reprints of this supplement and of the fourth supplement may each be obtained from the Business Office at fifty cents per copy. The Index, published in 1953 is also available at $2.50 per copy.

INDEX OF WELLS SHOT FOR VELOCITY

(Fifth Supplement)

STATE OF ALABAMA

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Baldwin	Temple	No. 1 Walsh, Ehle	Sec. 15, 8S - 4E	8,168	Shell	1956	Shell
Mobile	Gulf	No. 1 Citronelle Unit	25, 2N - 3W	11,457	SSC	1956	Gulf
Mobile	California	No. 1 Ladd Bros.	10, 1S - 1E	7,130	SSC	1955	California
Washington	Gulf	No. 1 Slade	18, 4N - 1W	7,900	SSC	1954	Gulf

STATE OF CALIFORNIA

Butte	Humble	No. B-4 Parrott Invest. Co.	Sec. 16, 20N - 1W	3,700	SSC	1955	CWVSG
Butte	Shell	No. 1 Peterson		3,145		1956	CWVSG
Colusa	Humble-Honolulu	No. 1 I. G. Zumwalt	23, 18N - 2W	4,474	SSC	1955	CWVSG
Colusa	Honolulu	No. 1-24 Zumwalt	24, 18N - 2W	5,287	SSC	1956	CWVSG
Colusa	Western Gulf	No. 1 Alexander	34, 14N - 2W	7,407	SSC	1956	CWVSG
Fresno	Los Nietos	Guijarral Service No. 55-22	22, 20S - 16E	8,786	United	1955	CWVSG
Fresno	Los Nietos	No. 75-1 Bourdieu	1, 21S - 16E	10,709	United	1955	CWVSG
Fresno	Highland	No. 1 Biancucci	31, 12S - 14E	5,466	Shell	1955	CWVSG
Fresno	Loyd A. Harnish	Guijarral Service No. 65-30F	30, 20S - 16E	9,647	United	1955	CWVSG
Fresno	Honolulu	No. 25 Indian-Westate	8, 19S - 17E	12,320	United	1955	CWVSG
Fresno	K.N.D.U.	No. 423-34J	34, 21S - 17E	11,700	Chevron	1955	CWVSG
Glenn	Shell	No. 1-53 Capitol Company	36, 20N - 2W	6,000	Western	1955	CWVSG
Glenn	Gen. Petroleum	No. 1 Moore-Benbow Unit	24, 19N - 2W	7,495			CWVSG
Glenn	Humble	No. 2 Mamie H. Porter	17, 18N - 2W	7,524	SSC	1956	CWVSG
Kern	Shell	No. 83-8 K.C.L.	8, 30S - 26E	10,000	SSC	1955	CWVSG
Kern	Getty	No. 23-9 Frick-Hogan	9, 31S - 29E	10,093	SSC	1955	CWVSG
Kern	Shell	No. 131-12 K.C.L.	12, 30S - 25E	12,400	SSC	1955	CWVSG
Kern	Standard	No. 22-16, K.C.L.-38	16, 28S - 26E	9,000	CRC	1955	CWVSG
Kern	Reserve	No. 63-20 Butler Wehr	20, 11N - 19W	9,500	SSC	1955	CWVSG
Kern	Chas. Jacobson	No. 1 Vista Grande Ltd.	22, 32S - 24E	8,148	SSC	1955	CWVSG
Kern	Shell	No. 1 Posuncula	12, 30S - 25E	14,200	Shell	1955	CWVSG
Kern	Reserve	No. D-2 Tejon Ranch	23, 11N - 19W	7,323	SSC	1955	CWVSG
Kern	Reserve	No. 56-30 Pauley	30, 11N - 18W	5,532	SSC	1955	CWVSG
Kern	Shell	K.C.L. 83-8	8, 30S - 26E		SSC		CWVSG
Kern	Western Gulf	No. 33-34 K.C.L.	34, 29S - 27E	11,572	Gulf-SSC	1956	CWVSG
Kern	K.C.L.-Doheny	No. 72-28 Conoco-Doheney	28, 29S - 25E	13,757	SSC	1956	BWVSG
Kern	Tidewater	No. 63A-8 S. Calif. Petr.	8, 30S - 21E	9,414	SSC	1956	CWVSG
Kern	Texas	No. 1 Breen	14, 28S - 23E	13,720	Western	1956	CWVSG
Kern	Western Gulf	No. 1 Shellabarger-Sheldon	30, 29S - 27E	10,848	SSC	1956	CWVSG
Kings	Middle Dome Corp.	No. 39-19V	19, 23S - 19E	12,750	SSC	1955	CWVSG
Madera	Shell	Merced-Madera Test No. 1	23, 9S - 15E	4,585	Shell	1953	CWVSG
Orange	Standard	No. 1 Pacific Community	26, 3S - 11W	7,487	Western	1955	CWVSG
Orange	Shell	No. 1 Anaheim-Sugar	9, 5S - 11W	11,450		1956	CWVSG
San Benito	Shell	No. 43-5 Shell-Artnell F&I	5, 17S - 11E	5,000	SSC	1955	CWVSG
San Luis	Humble	No. 1 Ed Borchert	2, 26S - 13E	6,225	SSC	1956	CWVSG
Tehama	Gen. Petroleum	No. 1 Monterey-Callaghan	22, 27N - 4W	7,687	SSC	1955	CWVSG
Ventura	Humble-Texas	No. 1 A. Nobel	2, 1N - 21W	7,010	SSC	1955	CWVSG
Ventura	Standard	No. 1 Kellner Unit	6, 1N - 22W	10,750	SSC	1955	CWVSG
Ventura	Standard	No. 2 Lucas	12, 1N - 22W	9,530	SSC	1955	CWVSG
Ventura	Texas	No. 1 Capital-Oxhard	5, 1N - 21W	10,900	Western-SSC	1956	CWVSG
Ventura	Standard	No. 2-1 C. W. West		15,212		1956	CWVSG
Ventura	Shell	No. 1 SPS North	21, 3N - 21W	10,798	SSC	1956	CWVSG
Ventura	Western Gulf	No. 1 Union-Laubacket	30, 1N - 21W	12,500	Western-SSC	1956	CWVSG

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Ventura	Standard	No. 1 Ballard-Mee	20, 2N-22W		SSC	1956	CWVSG
Yolo	Standard	No. 1 F. T. Swan	3, 6N- 3E	8,000	SSC	1955	CWVSG
Yolo	Gen. Petroleum	No. 65-10 Glide-Court	10, 7N- 3E	10,014	SSC	1955	CWVSG
			STATE OF COLORADO				
Adams	Lion	No. 1 Roloc	Sec. 14, 2S - 62W	8,500	SSC	1956	California
Arapahoe	Warren	No. 1 U. P. Lund	33, 4S - 62W	7,474	SSC	1954	G, W&G
Archuleta	L. A. Cada	No. 1 Federal	14, 34N- 6W	7,612	Western	1954	Stanolind
Bent	Conoco	No. 1 Wellman	1, 25S - 50W	5,530	Conoco	1956	Conoco
Bent	Conoco	No. 1 Hasser	28, 25S - 49W	5,348	Conoco	1956	Conoco
Dolores	Conoco	No. 1 Lone Dome	26, 40N- 16W	9,900	NGC	1955	Conoco
Dolores	Shell	Hawkins-Fed. No. 1 Dove Creek	13, 39N- 20W	6,505	Shell	1956	Shell
Elbert	Ginther, Warren & Ginther	No. 1 Carl Maul	17, 9S - 62W	7,524	SSC	1954	G, W&G
Elbert	Sinclair	No. 1 Taylor	13, 8S - 63W	8,039	SSC	1954	G, W&G
Garfield	Gen. Petroleum	No. 1 Schultz	15, 6S -103W	8,675	SEI	1953	Gen. Petroleum
Jackson	Carter	No. 1 McDanald	4, 10N- 8W	7,440	SSC	1956	RMSWSA
Jackson	Lion	No. 1 Eva	20, 10N- 79W	6,300	Gulf	1955	Gulf
Lamar	California	No. 1 Meyer	19, 8N- 68W	7,302	Shell	1953	Shell
Lamar	Allison	No. 1 Hummel	3, 6N- 68W	7,882	SSC	1954	California
La Plata	Worford Gas	No. 1 Unit "B"	10, 33N- 8W	7,533		1954	Stanolind
Logan	Shell	No. A-16 Green	30, 9N- 53W	7,725	Shell	1952	Shell
Logan	Shell	State of Colo. B-2	16, 8N- 53W	7,673	Seismic Inc.	1954	Shell
Mesa	Gulf	No. 1 Mulrooney	29, 8S - 97W	8,500	SSC	1955	Gulf
Moffat	Conoco	Thornburg No. 5	9, 3N- 91W	4,300	NGC	1956	Conoco
Moffat	Amerada	No. 1 Juniper Springs Unit	9, 5N- 94W	5,400	SSC	1956	Amerada
Montezuma	Gulf	No. 1 Fulks	27, 37N- 17W	8,730	Gulf	1955	Gulf
Morgan	Lion	No. 1 Kauffman	18, 1N- 56W	6,488	Lion	1955	Lion
Morgan	Shell	No. 1 Wulf	15, 6N- 58W	6,810	Shell	1952	Shell
Morgan	Superior	No. 43-42 Weiss	32, 3N- 55W	8,428	SSC	1955	California
San Miguel	Reynolds	No. 1 Egnar	14, 43N- 19W	10,211		1955	Stanolind
Weld	Osmund	No. 1 Dier	8, 2N- 67W	9,101	SSC	1955	California
Weld	California	No. 1 Sander	30, 6N- 64W	8,060	SSC	1955	California
Weld	Sloss & Brinkerhoff	No. 1 Nashland	24, 7N- 67W	9,132	SSC	1955	California
Weld	Rogers	No. 1 M. McFarlin	4, 8N- 65W	9,817	SSC	1954	RMSWSA
Weld	Murphy	No. 1 Painter-State	20, 3N- 62W	7,400	Shell	1952	Shell
Weld	Glasscock & Sloss	No. 1 Bradbury	15, 9N- 58W	7,692	Shell	1953	Shell
Weld	Superior	No. 16-14 Ball	14, 8N- 63W	8,835	SSC	1955	California
Weld	California	No. 1 Dier	8, 2N- 67W	9,101	SSC	1955	RMSWSA
Weld	Chicago	No. 1 Katchen	3, 2N- 65W	8,800	PGC	1955	Chicago
Weld	Brit. Am.	No. 1 Wise	19, 8N- 61W	10,300	SSC	1956	California
Weld	Ohio	No. 1 McVicar	30, 10N- 62W	9,100	SSC	1956	Ohio
Yuma	S. D. Johnson	No. 1 Clarkson Ranch	25, 5N- 45W	3,396	SSC	1955	Shell
			STATE OF FLORIDA				
Gadsden	Sun	No. 1 C. K. Wall	Sec. 25, 2N- 6W	4,215	SSC	1956	Sun & Gulf
Indian River	Amerada	No. 1 Mitchell	28, 31S -35E				Amerada
Jackson	Thompson	No. 1 Jas. J. Still	13, 5N-13W	3,900		1955	Humble
Jackson	Thompson	No. 1 B. K. Shivers	21, 5N- 7W	3,440		1955	Humble
Manatee	Magnolia	No. 1 Schroeder-Manatee	11, 35S -19E	11,220	Magnolia	1955	Magnolia
Washington	Thompson	No. 1 Ross Deal	4, 3N- 4W	4,150		1955	Humble
			STATE OF KANSAS				
Chautauqua	Frankfort	No. 1 Brazle	11, 33S - 9E	2,750	SSC	1955	Frankfort
Comanche	Conoco	No. 1 Cole	8, 34S -18W	6,426	Mayes-Bevan	1955	Conoco-Pure
Comanche	Pure	No. 1 Beal	5, 34S -17W	5,937	SSC	1955	Conoco-Pure
Crowley	Texas	No. 1 Walton	31, 33S - 4E	3,724	SSC	1956	Texas

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Edwards	Kewanee	No. 1 Samuel	29, 24S-19W	5,053	SSC	1956	Kewanee
Ellsworth	Frankfort	No. 1 Kuch	8, 14S-10W	4,290	SSC	1955	Frankfort
Harper	Anschutz	No. 1 Hoyt	7, 35S- 8W	5,075	Conoco	1955	Conoco
Haskell	Huber & Conoco	No. 1 Weirauch	23, 28S-31W	6,480	GC	1955	Conoco
Kingman	Jack Heathman	No. 1 Woodridge	16, 27S- 7W	4,301	Central	1954	Heathman
Logan	Gruenerwald	No. 1 Swart	12, 11S-32W	4,757	Central	1956	OKWSA
Morris	Stanolind	No. 1 B. V. Carpenter	29, 17S- 7E	2,148	Central	1955	Stanolind
Morton	Colorado Oil & Gas	No. 1 Hayward	9, 32S-42W	5,218	Central	1952	Colo. Oil & Gas
Ness	Atlantic	No. 1 J. R. Elmore	7, 16S-21W	4,472	CEC	1955	Atlantic
Pawnee	Bennett & Roberts	No. 1 Fox	31, 21S-18W	4,517	SSC	1956	Conoco
Rush	Republic Nat.	No. 1 Eva Webb "C"	16, 19S-20W	4,200	SSC	1954	Republic
Rush	Conoco	Solar No. 1 Schmidt	28, 16S-19W	3,840	SSC	1956	Conoco
Stanton	Killman & Hurd	Rorick Unit No. 1	18, 30S-42W	5,460	SSC	1956	Superior
Trego	Bennett & Roberts	No. 1 Kline	19, 14S-24W	4,504	SSC	1956	Conoco
			STATE OF LOUISIANA				
Bossier	Sunray Mid-Continent	No. 1 Crystal	Sec. 27, 21N-12W	9,200	SSC	1956	Sunray
Claiborne	Magnolia	No. 1 Wasson	13, 22N- 5W	11,008	SEI	1956	Magnolia
Jeff. Davis	Magnolia	No. 1 Broussard	13, 11S- 4W	14,960	Magnolia	1956	Union of La.-Gulf-Mag.
Lafayette	Sunray Mid-Continent	No. 1 Delma Hanks	20, 10S- 3E	15,010	SSC	1956	Sunray
La Fourche	Sun	No. 1 Drexler	66, 15S-15E	3,800	Schlumberger	1956	Sun
Madison	Atlantic	No. 2 Ayer Timber Co.	18, 15N-10E	9,110	Atlantic	1955	Atlantic
Plaquemines	Conoco	No. 1 B. 25, St. Lse. 2511	Main Pass Area (offshore)	9,999		1955	Phillips
St. Helena	Magnolia	No. 1 Smith-Cole	64, 2S- 5E	13,470	SSC	1955	Magnolia
St. Martin	Sohio-Tidewater-Welch	J. D. Johnson Unit No. 1	11, 9S- 5E	11,300		1955	Sohio
St. Mary	Texaco	No. 1 USAOCS-0313	46, Eugene Island Area	12,350	GGC	1956	Texaco
St. Mary	Warren	No. 1 Finkelstein	20, 16S-11E	13,019	General	1955	Warren
Terrebonne	Sun	No. 2 St. Lse. 2620	10, 23S-18E	16,238	Sun	1956	Sun & Pure
Calhoun	Seaboard	No. 1 J. L. Williams	35, 13S- 1E	6,849	United	1955	Seaboard & Honolulu
Jones	Union Producing	No. 1 Jones County	16, 7N-13W	13,517	SSC	1956	Group
Pearl River	Big Lane, Laub, Ballew	No. 1 Crosby Forest Prod.	20, 2S-16W	10,000	Humble	1956	Humble
Smith	California	No. 1 Ira Mayfield	9, 10N-14W	12,500	SSC	1956	California
			STATE OF MONTANA				
Big Horn	Tidewater	No. 1 Crow Tribal	Sec. 3, 3S-37E	8,790	SSC	1956	Tidewater
Big Horn	Rockhill	No. 1 Gill Cattle Co.	23, 9S-35E	3,873	SSC	1955	Shell
Big Horn	Shell	No. 8 Crow Tribal	25, 9S-37E	5,336	SSC	1955	Shell
Big Horn	Shell	No. 9 Crow Tribal	34, 9S-37E	5,219	SSC	1955	Shell
Big Horn	Shell	No. 10 Crow Tribal	32, 9S-37E	5,418	SSC	1955	Shell
Blaine	Phillips	No. 1 Fort Belknap "A"	3, 28N-23E	7,054	Phillips	1956	Phillips
Blaine	Tidewater	No. 1 Sam Unruh	32, 36N-19E	4,264	SSC	1956	Tidewater
Blaine	Amerada	No. 1 Anderson	4, 33N-23E	4,487	United	1955	Amerada
Carbon	Gulf	No. 1 Mackay	13, 6S-17E	5,285	Gulf	1955	Gulf
Carbon	Phillips	No. 1 Luoma "A"	28, 6S-20E	11,750	Phillips	1955	Phillips
Daniels	Richfield	No. 1 Madoc	31, 37N-49E	8,900	Shell	1955	Shell
Daniels	Union	No. 1 Nuhring	32, 35N-47E	9,263	United	1952	Union
Daniels	Calco	No. 1 Paulson	34, 33N-49E	7,000	SSC	1956	Calco
Dawson	Shell	No. 1 Richey	19, 23N-50E	10,500	Shell	1951	Shell
Dawson	Shell	N.P. 44-19	19, 23N-50E	7,821	Shell	1952	Shell
Dawson	Ajax	No. 1 Teague	19, 18N-56E	8,974	Shell	1952	Joint Venture
Dawson	Shell	33X-21	21, 14N-55E	9,256	United	1955	Shell
Dawson	Shell	Gas City 11-28	28, 14N-55E	9,460	United	1955	Shell
Dawson	Texaco	N.P. "G" NCT-2	21, 16N-54E	10,181	General	1952	RMSWSA
Dawson	Texaco	No. 1 Maciorski	25, 16N-50E	10,752	General	1952	Texaco
Fallon	Shell	Cabin Creek 11-33	33, 10N-58E	10,056	United	1954	Shell
Fallon	Shell	Carol Unit 33-22	22, 6N-60E	9,175	United	1954	Shell

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Fallon	Shell	N.P. 14-8	8, 4N-62E	8,430	United	1955	Shell
Fallon	McDonald & Eide	No. 1 Goodman Hilton	26, 10N-58E	9,200	United	1955	Shell
Fallon	Shell	Pannel 22X-36	36, 8N-59E	9,210	United	1955	Shell
Fallon	Rothschild	N.W.I. 44-15	15, 9N-59E	9,050	United	1955	Shell
Fallon	Shell	Beckman 42-2	2, 7N-59E	8,845	SSC	1956	Shell
Fergus	Seaboard-Cities Ser.	Dunphy	17, 10N-14E	2,700	SSC	1956	Seaboard
Garfield	Stanolind	N.P.F. 1	29, 18N-43E	9,020	United	1955	Shell
Glacier	Union	No. 1 Morning Gun	18, 31N-11W	9,352	United	1955	Union
Glacier	Union	No. 1 Lanside Butte-Tribal Unit 544	19, 37N- 8W	5,866	Union	1955	Union
Glacier	Union	Cadmus 470 No. 1 Miller	7, 33N- 6W	4,786	UGC	1955	Union
Lewis & Clark	Carl Yandt	Milford Colony No. 1	13, 18N -5W	6,708	Gulf	1955	Gulf
McCone	Shell	Golden-Gulch N.P. 1121 E	21, 23N-49E	9,810	United	1953	Shell
McCone	Marigold	No. 1 Farnham	14, 25N-48E	8,772	Shell	1952	Shell
McCone	Shell	N.P. 43-29B	29, 22N-48E	9,890	Shell	1953	Shell
McCone	Shell	N.P. 22-35A	35, 22N-47E	9,720	United	1953	Shell
McCone	Shell	Govt. 23-9	9, 24N-48E	9,400	SSC	1956	Shell
McCone	Shell	N.P. 14-5B	5, 22N-50E	9,640			Shell
McCone	Amerada	Rock Creek Unit No. 1	10, 22N-44E	9,100	United	1955	Amerada
Musselshell	Mobil	West Gage	36, 10N-24E	7,000	SSC	1956	RMSWSA
Musselshell	Carter	No. 1 Bedlam	8, 11N-29E	4,780	SSC	1955	Carter
Musselshell	Amerada	No. 1 Gunderson	10, 10N-27E	4,210	SSC	1955	Conoco
Musselshell	Amerada	No. 1 Taylor	22, 10N-25E	3,073	SSC	1955	Amerada
Musselshell	Amerada	No. 1 Klos "A"	23, 10N-25E	3,580	SSC	1956	Amerada
Musselshell	Amerada	N.P.C. No. 2	11, 10N-28E	4,336	United	1956	Amerada
Phillips	Shell	Gulf Frenchman Fed. 1	31, 37N-34E	6,092	Southern	1953	Shell
Prarie	Shell	N.P. 32X-3B	3, 12N-56E	9,040	United	1954	Shell
Prarie	Shell	34-13B	13, 12N-56E	9,091	United	1955	Shell
Roosevelt	California	No. 1 Grim	13, 32N-49E	9,746	United	1955	California
Rosebud	Richfield	No. 1 Cherry Creek	32, 11N-36E	4,158	SSC	1955	Richfield
Rosebud	F. R. Anderson	Govt. 31-2	2, 12N-40E	8,595	United	1953	Shell
Rosebud	Shell	Lame Deer Core Hole 5	9, 2S-44E	2,000	Expl. Service	1952	Shell
Rosebud	Shell	Lame Deer Core Hole 6	30, 2S-42E	2,705	Expl. Service	1952	Shell
Rosebud	Amerada	No. 1 Cherry Creek Sheep Co.	35, 13N-39E	5,290	SSC	1956	Amerada
Sheridan	H. L. Hunt	No. 1 Hagen	7, 34N-52E	9,470	United	1952	Carter
Sheridan	Amerada	No. 1 Lander	21, 37N-52E	5,950	United	1955	Amerada
Sweetwater	Conoco	No. 1 Govt. (Countryman Creek)	33, 2S -19E	8,732	SSC	1956	Conoco
Teton	Christie, Mitchell & Mitchell	Rockport Colony-Weiser No. 1	30, 27N- 7W	4,220	Gulf	1956	Gulf
Teton	Phillips	No. Randell	6, 21N- 5W	6,754			Phillips
Teton	Lion-Brown	No. 1 Hodgkiss	10, 22N- 6W	3,920	Gulf	1955	Gulf
Teton	Gulf	No. 1 Teton-Knowlton	8, 26N- 5W	6,500	SSC	1956	Gulf
Valley	Gulf-Carter-Sinclair	No. 1 Lentzner	9, 32N-42E	8,367	United	1955	Shell
Valley	Seaboard	No. 1 Loberg	26, 30N-36E	7,755	SSC	1956	Shell
Valley	Phillips	No. 1-A Schultz	24, 30N-45E	8,990	SSC	1956	Carter
Valley	Murphy	No. 1 Firemoon	12, 30N-41E	8,242	Seis. Anal.	1954	Murphy
Valley	Gulf	No. 1 Cornwell	14, 30N-38E	7,010	Gulf	1952	Gulf
Valley	Seaboard	Honolulu Rickter	18, 32N-38E	7,527	Seaboard	1955	Seaboard
Wibaux	Conoco	No. 1 Max Beggar	34, 12N-60E	10,919	SSC	1955	Conoco
Wibaux	Shell	Pine 23-22A	22, 11N-57E	9,100	United	1955	Shell
Wibaux	Shell	Pine 43-22A	22, 11N-57E	10,396	United	1955	Shell
Yellowstone	Atlantic-Stanolind	No. 2 Horton Est.	18, 7N-32E	6,140	SSC	1956	Atlantic
			STATE OF NEBRASKA				
Box Butte	Shell	No. 1 Wildy	Sec 1, 28N-48W	4,375	Shell	1952	Shell
Box Butte	J. N. Wood	No. 51-13	13, 27N-51W	3,147			Shell
Box Butte	United	No. 1 Royster Pierce	22, 26N-49W	3,003	Dayton Expl.	1952	RMSWSA

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Chase	Ohio	No. 1 Joe Rothmeier	24, 8N-37W	4,900	SSC	1956	Ohio
Cheyenne	Superior	No. 35-19 Anderson	19, 15N-52W	5,550	Superior	1955	Superior
Dawes	Calco	No. 1 Soester	2, 30N-51W	5,730	SSC	1956	Calco
Garden	Sohio	No. 1 Richards	27, 17N-43W	3,390	SSC	1956	Sohio
Garden	Ohio	No. 1 Ferrell	25, 18N-45W	5,908	SSC	1955	Ohio
Kimball	Shell	No. 1-B Schmid	12, 16N-54W	7,578	SSC	1956	Shell
Sheridan	Shell	No. 1 Jaggers	1, 27N-46W	3,030	Shell	1952	Shell
Sheridan	Shell	No. 2 Jaggers	22, 28N-46W	2,731	Shell	1952	Shell
Sioux	Conoco	No. 1 Rohrer	9, 26N-57W	6,037	Petty	1955	Conoco
			STATE OF NEW MEXICO				
Chaves	Conoco	L. T. White No. 19-1	Sec. 19, 9S - 28E	7,190	Schlumberger	1956	Conoco
Chaves	De Kalb & Los Nietos	No. 1-X J. P. White	28, 10S - 29E	9,098	United	1952	Union
Chaves	Atlantic	No. 1 Federal "Union"	7, 11S - 31E	10,754	UGC	1955	Atlantic
Chaves	Phillips	No. 1 James "A"	34, 11S - 31E	12,310	Empire	1955	Atlantic
Chaves	Intex Trig	No. 1-26 Federal	26, 12S - 26E	6,720		1955	Stanolind
Chaves	Honolulu	No. 1 Malco Federal	15, 14S - 28E	10,200	United	1956	Honolulu
Chaves	Ralph Lowe	No. 1 Amerada-Wise	H, 20S - 38E	9,505	Dawson	1955	Lowe
Chaves	Texas Crude	No. 1-16 State	16, 14S - 30E	10,858	Chevron	1955	S.O.T.
Chaves	Gulf	No. 1 Federal Hinkle	21, 13S - 30E	10,500	Empire	1955	Gulf
Eddy	Stanolind	No. 1 Welch Unit	21, 26S - 27E	11,884	Empire	1954	Stanolind
Eddy	Ibex Hanson	No. 1 Federal	25, 26S - 31E	4,091		1954	
Eddy	Aldridge & Stroud	No. 1 State	3, 26S - 28E	2,535		1956	Stanolind
Eddy	Humble	No. 1 Huapache Unite No. 1	35, 23S - 22E	12,518	Schlumberger	1955	Humble
Eddy	Union	No. 1 Federal White	17, 24S - 22E	6,740	Magnolia	1956	Magnolia
Eddy	Humble	No. 1 Chalk Bluff Draw	5, 18S - 27E	10,400	Humble	1956	Humble
Guadalupe	General Crude	No. 1 Simpson	21, 10N- 23E	9,130	Petty	1955	Gen. Crude
Lea	Conoco	No. 1 Lane Ranch	9, 10S - 31E	12,250	Conoco	1955	Conoco
Lea	Feldman-Union	No. 1 State	7, 11S - 38E	11,900	Midland Geo.	1956	Union
Lea	McAlester Fuel	No. 1 "EL" State	7, 15S - 35E	14,200	Midland Geo.	1956	Union
Lea	Jake L. Hamon	No. 1 Landreth Federal	20, 10S - 38E	12,509	UGC	1955	Atlantic
Lea	Atlantic	No. 1 Daisey Chambers	26, 15S - 35E	13,990	Empire	1955	Atlantic
Lea	Union	No. 1 Gilmore Federal	21, 22S - 32E	8,601		1954	Stanolind
Lea	Stanolind	No. 1 Buffalo Unit	3, 19S - 33E	14,125	Empire	1954	Stanolind
Lea	Hunt	No. 1 State	14, 15S - 34E	14,821	Empire	1954	Stanolind
Lea	Ohio	Sunshine Royalty No. 1 Fed.	34, 25S - 32E	4,050		1955	Stanolind
Lea	Caroline Hunt Estate	No. 1 State	18, 12S - 34E	13,236	Empire	1955	Stanolind
Lea	Cities Service	No. 1 State "AU"	10, 17S - 26E	8,600		1955	Stanolind
Lea	Conoco	No. 1 Nolan-Federal	21, 25S - 34E	5,602		1956	Stanolind
Lea	Warren	No. 1 Fed. Simons	7, 9S - 38E	11,616	Magnolia	1955	Magnolia
Lea	Humble	No. AH-1 NM State	36, 15S - 34E	13,425	Humble	1955	Humble
Lea	Hamon	No. 1 State "E"	32, 12S - 34E	13,326	Gulf	1955	Gulf
Lea	Sunray-Mid-Cont.	No. 1 E. Bagley Unit	9, 12S - 34E	13,090	Republic	1955	Sunray
Lea	Sunray-Mid-Cont.	No. 1 O. E. Fulton	6, 13S - 38E	12,268	SSC	1955	Sunray
Lea	Sunray-Mid-Cont.	No. 1 New Mex. St. "F"	1, 10S - 33E	12,570	SSC	1955	Sunray
Lea	Olson	San Hills Unit No. 1	13, 26S - 35E	12,450	Sinclair	1955	Sinclair
Lea	Sinclair	No. 1 H. P. Saunders	3, 18S - 38E	11,480?		1955	Sinclair
Lea	Sinclair	No. 1 J. P. Dean	35, 15S - 30E	13,865	Sinclair	1955	Sinclair
Lea	Shell	No. 1 Hooper	27, 10S - 35E	13,893	Shell	1955	Shell
Lea	Shell	No. 1 Williams Unit	8, 16S - 34E	14,075	Shell	1955	Shell
Lea	Conoco	No. 1 Williams Ranch Unit	20, 16S - 32E	13,720	Sinclair	1955	Sinclair
Lea	Ohio	No. 1 Slatton	1, 9S - 37E	11,840	Magnolia	1956	Magnolia
Lea	Superior	No. 1-335 State	19, 13S - 32E	12,519	General	1954	Superior
Lea	Phillips	No. 1 ETZ Federal	1, 21S - 32E	15,810	SSC	1956	Phillips
McKinley	Pure	No. 1 Navajo Tribe-Tract 9	29, 19N- 17W	7,052		1954	Stanolind

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Otero	Plymouth	No. 1 Federal	15, 20S - 9E	7,270		1954	Stanolind
Rio Arriba	Magnolia	No. 1-A Jicarilla	18, 25N- 2W	13,500	Magnolia	1955	Magnolia
Roosevelt	Magnolia	No. 1 Martin	29, 6S - 34E	8,055	Magnolia	1955	Magnolia
Roosevelt	Shell	No. 2 Blutt	16, 8S - 37E	12,575	Magnolia	1955	Magnolia
Roosevelt	Gulf	No. 1-C Stevenson	22, 4S - 31E	7,048			Gulf
San Juan	Gulf	No. 1 Navajo Federal	28, 25N- 16W	10,009	Stanolind	1955	Stanolind
San Juan	Humble	No. B-1 Navajo	29, 32N- 20W	6,845	Humble	1956	Humble
San Juan	Humble	No. C-1 Navajo	8, 31N- 18W	8,075	Humble	1956	Humble
			STATE OF NORTH DAKOTA				
Billings	Texaco	Govt. No. 1 Pace	31, 144N-100W	9,890	United	1955	Texaco
Billings	Amerada	No. 1 Herman May	9, 139N-100W	13,315	Amerada	1953	Amerada
Bottineau	Cardinal	No. 1 Thompson	5, 161N- 78W	3,634	United	1955	California
Burke	Stanolind	No. 1 Peterson	22, 163N- 89W	5,573	SSC	1955	Stanolind
Burke	Calvert	No. 1 G. K. Milby	16, 162N- 90W	6,050	SSC	1955	Stanolind
Dunn	Mobil	No. 1 Bird Bear	22, 149N- 91W	8,185	UGC	1955	Mobil
Eddy	Calvert	State "A"	16, 150N- 67W	4,235	Shell	1953	Shell
McKenzie	Gulf	No. 1 Bennie Pierre Federal	28, 148N-104W	13,480	SSC	1956	Gulf
McKenzie	Texaco	No. 1 Keogh	5, 151N- 95W	9,350	SEI	1955	Texaco
McKenzie	Texaco	No. 1 O. J. Anderson	30, 151N- 95W	9,588	United	1955	Texaco
McLean	Stanolind	No. 1 McLean	28, 150N- 80W	7,084	Stanolind	1952	Stanolind
Ramsey	Johnson	No. 1 Wolf	17, 158N- 62W	3,269	Shell	1953	Shell
Ward	Calvert	No. 1 Harriet Sinclair	23, 160N- 89W	6,110	SSC	1955	Stanolind
Williams	Texaco	No. 1 Donahue	23, 154N-100W	14,000	Texaco & SSC	1956	Texaco
			STATE OF NEVADA				
Elko	Gulf	No. 2 Wilkins Ranch	Sec. 19, 39N-69E	4,900	Gulf	1954	Gulf
Elko	Gulf	Mary's River Fed. No. 1	16, 41N-60E	6,600	Gulf	1955	Gulf
Nye	Shell	No. 1 Lockes Unit	3, 8N-50E	7,300	Shell	1955	CWVSG
Nye	Shell	No. 2 Eagle Springs Unit	2, 7N-56E	10,006	Shell	1954	CWVSG
Nye	Shell	No. 17-34 Eagle Springs Unit	34, 9N-57E	9,511	Shell-SSC	1956	CWVSG
Nye	Shell	No. 1 Eagle Springs Unit	35, 9N-57E	10,300	Shell	1954	CWVSG
			STATE OF OKLAHOMA				
Atoka	Gulf	No. 1 Butler	Sec. 21, 3S-10E	7,246	Gulf	1954	Gulf
Beckham	Rogers Fain	No. 4 Windel	31, 9N-23W	6,490	Shell	1953	Shell
Beckham	Carter	No. 1 Carter-Caughron	19, 10N-21W	15,000	Shell	1953	OKWSA
Bryan	Pasotex	No. 1 Griffin	25, 6S - 8E	11,282	Western	1955	Pasotex
Bryan	Phillips	No. 1 Matoy	24, 5S -11E	10,280			Phillips
Carter	Frankfort	No. 2 Williams	12, 5S - 2W	9,455	SSC	1954	Frankfort
Cimmaron	Texaco	No. 1 Pugh	34, 3N- 9E	5,666	Western	1955	Texaco
Cleveland	Pure	No. 1 Smith	30, 8N- 1W	7,858		1954	Pure
Coal	Gibson & Holliman	No. 1 Thomas	10, 1S - 9E	5,205	SSC	1953	H. F. Gibson
Comanche	Frankfort	No. 1 Poaf-py-bitty	4, 1S -11W	6,250		1955	Frankfort
Comanche	Kingwood	No. 1 Collier	27, 3N- 9W	8,640	Texas	1954	Kingwood
Dewey	Sinclair	No. 1 Kunc	11, 17N-18W	8,700	SSC	1956	OKWSA
Garvin	Superior	No. 1 Glover	7, 4N- 2W	8,520	SSC	1955	Superior
Garvin	Pure	No. 1 Trahern	32, 4N- 1E	5,606		1955	Pure
Grady	Superior	No. 1 Mowdy	13, 6N- 5W	14,140	SSC	1955	Superior
Grady	Superior	No. 1 Perry Unit	3, 5N- 5W	14,136	SSC	1955	OKWSA
Grady	Blackwood-Nichols	No. 1 Standridge-Hendrix	4, 6N- 6W	12,040	SSC	1955	Gulf
Grady	Frankfort & Inland	No. 1 Mayor	1, 3N- 8W	9,258	SSC	1955	Frankfort
Grady	Rotary Dev. & Humphrey	No. 1 Coleman-Davis	20, 8N- 7W	13,480	SSC	1955	Rotary Dev.
Grant	Union	No. 1 Arterburn	9, 28N- 5W	5,618	UGC	1954	Union
Grant	Union	No. 1 Emenhiser	23, 3S -17W	5,818		1954	Union

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Grant	Frankfort & Inland	No. 1 Mayor Drlr.	1, 3N- 8W	9,258	SSC	1955	Frankfort
Grant	Union	No. 1 Dickey	29, 29N- 6W	5,235	UGC	1953	Union
Greer	Kingwood	No. 1 Darden	20, 4N-23W	7,500	Gulf	1955	Gulf
Harper	Magnolia	No. 1 Stinson	12, 26N-25W	7,536	Magnolia	1956	Magnolia
Haskell	Superior	No. 1 Gordon	16, 8N-20E	5,543	SSC	1955	Superior
Johnston	Shell	No. 1 Chapman	6, 4S - 5E	5,014	Shell	1953	Shell
Kay	Conoco	No. 1 Brett "A"	8, 25N- 2E	5,314	SSC	1956	Conoco
Kay	Jernigan & Morgan	No. 1 Cottman	17, 25N- 1E	4,046	SSC	1955	Gulf
Marshall	Quinton Little	No. 1 Rennie Reed	35, 4S - 5E	10,435	SSC	1045	OKSWA
Marshall	Pure	No. 1 Rowland	31, 7S - 5E	9,041	Precision Ex.	1953	Pure
McLain	Superior	No. 1 Haney	17, 5N- 1W	8,580	SSC	1956	Superior
McLain	Magnolia	No. 1 Tuggle	2, 6N- 2W	9,192	Magnolia	1955	Magnolia
McLain	Gulf	Nol 1 Cora Dyer	20, 6N- 3W	11,034	SSC	1956	OKWSA
Murray	Frankfort	No. 1 Sparks Ranch	32, 1S - 1W	9,990	SSC	1956	Frankfort
Osage	Phillips & Brockman	No, 1-A Conness	14, 20N- 9E	2,180		1955	Phillips
Osage	Atlantic	No. 1 Osage "C"	13, 26N- 6E	2,980	SSC	1956	Atlantic
Osage	Texas	No. 7 Great Spirit	31, 26N- 6E	2,983	SSC	1954	Carter
Pontotoc	Atlantic	No. 1 W. E. Harvey	27, 3N- 5E	4,710	SSC	1956	OKWSA
Pottawatomie	Cities Service	No. 1 State "L"	16, 11N- 3E	5,900	SSC	1956	OKWSA
Pottawatomie	Magnolia	No. 1 McGee	24, 8N- 3E	5,214	Magnolia	1955	Magnolia
Roger Mills	Carter	No. 1 Hartley	34, 14N-26W	11,900	Shell	1953	OKSWA
Stephens	Clark & Cowden	No. 1 Waters	12, 1S - 7W	6,547	SSC	1956	Lone Star
Stephens	Lone Star	No. 1 Hill Trust	26, 1S - 7W	5,718	SSC	1956	Lone Star
Tillman	Sunray	No. 1 Tah-Quint-Ter-Up	21, 4S -16W	6,128	OGC	1955	Sunray
Washita	Shell	No. 1 Counts	29, 9N-20W	13,916	Shell	1953	Shell
Washita	Shell	No. 1 Galloway	21, 8N-18W	6,456	Shell	1954	Shell
Woods	Gulf	No. 1 Zimmerman	12, 28N-18W	6,500	Gulf	1954	Gulf
Woods	Amerada	No. 1 F. O. Smith	21, 24N-13W	7,500	SSC	1956	Amerada
Woodward	Magnolia	No. 1-A Borden	22, 20N-20W	13,480	Magnolia	1956	Magnolia
			STATE OF SOUTH DAKOTA				
Butte	Shell	No. 1 W. Johnson 23-23	23, 10N- 1E	4,515	SSC	1956	Shell
Butte	Amerada	No. 1 State	4, 14N- 4E	7,760	Dayton Expl.	1953	Amerada
Fall River	Shell	No. 1 Bert Thompson	2, 8S - 8E	2,700	SSC	1955	Shell
Harding	Richfield	No. 1 State	16, 17N- 4E	8,136	SSC	1955	Richfield
Harding	Shell-Carter	No 1 Clarkson Hanson	28, 21N- 3E	9,025	United	1955	Shell
Jones	Shell	No. 1 A. E. Herman	15, 1N-20E	2,530	Shell	1954	Shell
Jones	Shell	No. 2 A. E. Herman	3, 1N-20E	3,205	Shell	1954	Shell
Perkins	Evans-Querbes Trust	No. 1 Capp	9, 13N-16E	7,300	Shell	1953	Shell
			STATE OF TEXAS				
Anderson	Higgins Cone & Cone	No. 1 Cone	Wm. Kimbro Sur., A-34	5,807		1955	Stanolind
Anderson	Texaco	No. 1 E. C. Williams	T. H. Kinsley Sur., A-450	6,190			Texaco
Andrews	C.S.O.	No. 1 King "B"	Sec. 22, B.A.-46, P.S.L.	12,105	United	1954	CSO
Andrews	Lawton	No. 1-A Bird	Sec. 33, B.A.-19, P.S.L.	12,670	Shell	1955	Shell
Andrews	Fasken	No. D-1 Tee	Sec. 12, B.-40, T-3N, G&MMB&A	13,703	Magnolia	1955	Magnolia
Andrews	Magnolia	No. 1-DD Fasken "GA"	Sec. 16, B.-40, T-1N, T&P	13,450	Magnolia	1955	Magnolia
Andrews	White Eagle	No. 1 Argo Oil Co.	Sec. 14, B.-A-41, P.S.L.	9,290	Empire	1955	White Eagle
Andrews	Champlin	No. 1 Univ. "K"	Sec. 11, B.-5, U.L.S.	12,618	Empire	1955	Champlin
Andrews	Humble	No. 1-C J. S. Means	Sec. 2, B.-A-45, P.S.L.	14,325	Humble	1955	Humble
Andrews	Texaco	No. 1 State "AX"	Sec. 37, B.-6, U.T.L.	12,850	Texaco	1955	Texaco
Andrews	Signal	No. 1 Parker	Sec. 8, B.-A-51, P.S.L.	11,900?		1955	Sinclair
Andrews	Stanolind	No. 1 Univ. "BV"	Sec. 8, B-4, U.L.	4,895	SSC	1955	Stanolind
Andrews	Stanolind	No. 1 Univ. "BZ"	Sec. 5, B.-5, U.L.	4,880	SSC	1955	Stanolind
Andrews	Stanolind	No. 1 Univ. "BT"	Sec. 5, B.-4, U.L.	4,638	SSC	1955	Stanolind
Andrews	Honolulu	No. 6 Parker "C"	Sec. 18, B.-A-46, P.S.L.	12,880	United	1955	Honolulu
Andrews	Atlantic	No. 1 University "5"	Sec. 30, B.-5, U.L.	13,885	Empire	1956	Atlantic

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Andrews	Texaco	No. 1 University "BD"	Sec. 15, Univ. Blk. 11	9,062			Texaco
Andrews	Humble	No. 1 Elizabeth Armstrong	Sec. 11, B.-A-45, P.S.L.	14,150	Humble	1956	Humble
Andrews	Humble	No. 209, J. S. Means	Sec. 1, B.-A-19, P.S.L.	10,895	Humble	1956	Humble
Bandera	General Crude	No. 1 S. H. Anderson	GH&SA Sur. No. 21	10,011	Petty	1955	Petty
Baylor	Pure	No. A-1 Waggoner Est.	Sec. 156, B-BB&CRR	6,093	Empire	1955	Pure
Borden	Magnolia	No. 1 York	Sec. 279, B.-97, H&TC	8,500	Magnolia	1955	Midwest
Borden	Midwest	No. 1 Scott	Sec. 413, B.-97, H&TC	8,340	Empire	1956	Midwest
Calhoun	Humble	No. 3 Maude B. Traylor	Juan Maldonado Sur.	8,380	Schlumberger	1956	Humble
Callahan	Humble	No. 1 Petcher	A. Poettcher Sur.	4,878	Texas Seis	1955	Humble
Cameron	Magnolia	No. 1 Kerlin	Padre Island-Gulf Blk. 1169 (offshore)	14,300	Magnolia	1956	Magnolia
Cameron	Humble	No. 1 L. D. Austin	Ojo de Agua Gr.-Blk. 14	10,954	Schlumberger	1956	Humble
Cameron	Humble	No. 1 Water Control Dist. 6	Five miles NW Brownsville twst.	11,950	Schlumberger	1956	Humble
Camp	Placid-Phillips	No. 1 L. F. Wilson	A. C. Peck Sur., A.-97	12,848	Petty	1955	Shell
Chambers	Texaco	No. 1 Fitsgerald	N.E. Flank Barbers Hill Dome	4,777			Texaco
Cherokee	Humble	No. 13 H. L. Carter	P.O. Lumpkin Sur. A-512	13,013		1955	Humble
Childress	W. H. Griggs	No. 1 R. A. Smith	Sec. 52, B.-H, AP&M	7,873	Schlumberger	1955	Shell
Cochran	Union	No. 1-10 Culp	Sec. 10, B.-Z	11,850	Midland Geo.	1956	Union
Coke	Humble	No. 2 H. H. Weaver	Sec. 16, I. N. Morlan Sur.	6,593	Humble	1955	Humble
Coke	Randle	No. 1 Harrington	Sec. 22, B.-16, H&TC	7,543	Empire	1955	Stanolind
Coke	Forest	No. 1 W. B. Wilson	Sec. 11, B.-16, H&TC	7,270	Empire	1955	Stanolind
Coke	Sid Katz	No. 2 Rawlings	Rubio Sur. No. 23	7,010	Empire	1954	Stanolind
Coke	La Gloria & Dykes	No. 1 Reed	Sec. 3, B.-2, GC&SF	6,733	Empire	1954	Stanolind
Coke	Harper & Huffman	No. Eubanks	Sec. 447, B.-1-A, H&TC	6,155	Empire	1954	Stanolind
Coke	Highland	No. 1 Mendenhall	Sec. 247, B.-2, H&TC	7,971		1956	Stanolind
Concho	Humble	No. 1 Ellon Sims	B.-72, W. Kramer Sur.	5,060	Texas Seis	1955	Humble
Crane	Gulf	No. 1 T. C. Barnsley	Sec. 33, B.-32, P.S.L.	8,360	Empire		Gulf
Crane	Gulf	No. 2 Dawson Est. "A"	Sec. 12, B.-6, H&TC	6,685	Empire		Gulf
Crane	Gulf	No. 183 Waddell	Sec. 13, B.-B-26, P.S.L.	11,860	Empire		Gulf
Crane	Gulf	No. 226 Waddell	Sec. 67, B.-X, CCSD&RGNG	8,902	Empire		Gulf
Crane	Gulf	No. 229 Waddell	Sec. 14, B.-4, H&TC	7,975	Empire		Gulf
Crane	Gulf	No. 231 Waddell	Sec. 17, B.-B-21, P.S.L.	6,063	Gulf		Gulf
Crane	British-Amer.	No. 1 Tubb "B"	Sec. 18, B.-20, P.S.L.	8,290	SSC	1954	British-Amer.
Crane	Gulf	No. 103 W. N. Waddell	Sec. 2, B.-B-25, P.S.L.	11,300	Empire	1955	Gulf
Crane	Buffalo	Delta-Gulf No. 1 Tubb	Sec. 16, B.-B-27, P.S.L.	6,467	Empire	1955	Gulf
Crane	American	No. 1-E McKnight	Sec. 19, B.-B-17, P.S.L.	7,795	Empire	1955	Gulf
Crane	Liedtke, et al.	No. 1 Texas Amer. Synd.	Sec. 23, B.-4, H&TC	5,961	Schlumberger	1955	Union
Crane	Liedtke, et al.	No. 1 Texas Amer.	Sec. 23, B.-5, H&TC	5,820	Schlumberger	1955	Union
Crane	Gulf	No. 311 W. N. Waddell	Sec. 22, B.-B-21, P.S.L.	5,830			Gulf
Crane	Gulf	No. 6 Jax M. Cowden	Sec. 33, B.-2, H&TC	6,235			Gulf
Crane	Evans	No. 2 Payton Royalty	Sec. 101, D. L. Frost Sur.	7,750			Gulf
Crane	Gulf	No. 339 W. N. Waddell	Sec. 21, B.-B-21, P.S.L.	5,910			Gulf
Crane	Gulf	No. 330 W. N. Waddell	Sec. 19, B.-B-21, P.S.L.	6,050			Gulf
Crane	TXL Oil Corp.	Seaboard No. 1 TXL "D"	Sec. 31, B.-42, T-4S, T&P	12,962	EVSC	1956	TXL
Crockett	Chambers-Kennedy	No. 1 Andrews	Sec. 43, B.-UV, GC&SF	7,800	Empire		Gulf
Crockett	Magnolia	No. 1 Shannon Hospital "B"	Sec. 28, B.-BB, EL&RR	9,740	Magnolia	1955	Magnolia
Crockett	Pure	No. 1-C University	Sec. 26, B.-7, U.L.	8,789	Empire	1955	Pure
Crockett	Superior	No. 1-22 Shannon	Sec. 22, B.-BB, EL&RR	9,895	Empire	1955	Superior
Crockett	Southern Union Gas	No. 1 Glasscock	Sec. 41, B.IJ, GC&SF			1955	Sinclair
Crockett	Stanolind	No. 1 University "BP"	Sec. 28, B.-46, U. L.	7,890	Empire	1955	Stanolind
Crockett	Craig	No. 1 M. C. Smith "15"	Sec. 13, B.-AB, D&SE	8,038	Magnolia	1956	Magnolia
Crockett	Pure	No. 1-D University	Sec. 11, B.-44, U.L.	9,481	Empire		Pure
Crockett	T.P.C.&O.	No. 1 University "M"	Sec. 36, B.-12, U.T.L.	9,934		1955	T.P.C.&O.
Crockett	Willets & Craig	No. 1 Childress Smith	Sec. 13, B.-AB, D&SE	8,045	Magnolia	1956	Magnolia
Crockett	Phillips	No. 1-R University	Sec. 21, B.-42, U.L.	8,715			Phillips
Dallam	Conoco	No. 1 A. S. A. Willis	Sec. 81, B.-7, CSS	7,803	Conoco	1955	Conoco
Dallas	Magnolia	No. 1 Trigg Est.	T. W. Cousey Sur. A-316	10,203	Magnolia	1955	Magnolia

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Dawson	Seaboard	No. 1 W. G. Reed	Sec. 35, B.-34, T-4N, TPRR	9,300	Rayflex	1955	Seaboard
Dawson	Shell	No. 1 Ellen Clay	Lab. 4, Lge. 267, Moore CSL	12,825	Shell	1955	Shell
Dawson	Superior	No. 1 Barnes McBrayer	Lab. 24, Lge. 271, L.C.S.L.	12,595	Empire	1956	Superior
Dawson	Humble	No. 1 J. R. Weaver	League 1, Taylor C.S.L.	12,705	Humble	1950	Humble
Denton	Hall & Glasco	No. 1 Carroll	Patrick O'Leary Sur. A-975	8,780	Gulf		Gulf
Ector	Sun	No. 1 Sallie Ratliff	Sec. 35, B.-42, T-1S, T&P	14,100	United	1956	Sun
Ector	C.S.O.	No. 1 TXL "O"	Sec. 21, B.-45, T-1N, T&P	9,450	Empire	1954	CSO
Ector	Texas-Gulf	No. 4 McKnight	Sec. 18, B.-41, T-2S, T&P	12,150	Empire		Gulf
Ector	Williamson & Roden	No. 1 Parker	Sec. 12, B.-45, T-2S, T&P	12,446	Empire	1955	CSO
Ector	Humble	No. 1 R. L. York	Sec. 14, B.-44, T-3S, T&P	12,410	Humble	1955	Humble
Ector	Wm. D. McBee	No. 1 TXL	Sec. 33, B.-42, T-3S	14,254	United	1955	SSWSA
Ector	Sinclair	No. 11 Marcus Gist	Sec. 32, B.-42, T-1S, T&P	13,900?		1955	Sinclair
Ector	Sun	No. 1 Ratliff	Sec. 35, B.-42, T-1S, T&P	14,100	United	1955	Sun
Ector	T.P.C.&O.	No. B-1 J. Lee Johnson, Jr.	Sec. 37, B.-44, T-1S, T&P	12,750	Empire	1955	SSWSA
Ector	Ada Oil Co.	No. 1 Cowden Est.	Sec. 1, B.-42, T-3S, T&P	12,100		1956	Stanolind
Ector	Stanolind	No. 1 D. Faskin "AK"	Sec. 33, B.-42, T-1N, G&MMB&A	10,485		1956	Stanolind
Ector	Gulf	No. 772 Goldsmith	Sec. 17, B.-44, T-1S, T&P	9,720			Gulf
Ector	Gulf	No. 774 Goldsmith	Sec. 40, B.-44, T-1S, T&P	11,640			Gulf
Ector	Phillips	No. 3 Millard "E"	Sec. 16, B.-B-15, P.S.L.	9,812			Phillips
Ector	Magnolia	No. 1 Ratliff	Sec. 38, N.-42, T-1S, T&P	13,610	Magnolia	1956	Magnolia
Ector	C.S.O.	Scharbauer "C"	Sec. 10, B.-B-15, P.S.L.	9,056	Empire	1956	C.S.O.
Ector	C.S.O.	No. 1 Parker "B"	Sec. 29, B.-44, T-2S	12,510	Empire	1956	C.S.O.
Ector	Sunray Mid-Continent	No. 1 Ector County	Sec. 46, B.-12, T-1S, T&P	13,900	SSC	1956	Sunray
Edwards	Seaboard	No. 1 Szalwinski	660' FNEL & 660' FSEL 11238 84 ac lse, Marchaca Sur.	11,238	Rayflex	1954	Seaboard
Edwards	Stanolind	No. 1 Midland Forms "AJ"	Sec. 37, B.-42, T-1N, G&MMB&A	13,221	Stanolind	1955	Stanolind
Edwards	Humble	No. 1 Meier	Menard C.S.L. Sur.	7,000	Schlumberger	1956	Humble
Frio	Amerada	No. 1 F. C. McKinney	Sur. 61¼-Abst. 910-F	8,240	GRC	1955	Amerada
Gaines	Scott-Hammond	No. 1 University	Sec. 1, B.-6, U.T.L.	13,000	Schlumberger	1955	Ada Oil Co.
Gaines	Tidewater	No. 1 Wimberly	Sec. 305, B.-G, CCSD&RGNG	11,840	SSC	1955	Tidewater
Gaines	Placid	No. 1 Ida Dalmont	Sec. 70, B.-H, D&W	14,005	Empire	1955	Hunt
Gaines	Felmont	No. 1 Oil Development	Sec. 100, B.-H, D&W	14,222	Schlumberger	1955	Felmont
Gaines	Humble	No. 1 T. S. Riley "B"	Sec. 259, B.-G, WTRR	11,600	Humble	1955	Humble
Gaines	Hamon-Sun	No. 1 Oil Development	Sec. 81, B.-G, WTRR	13,490	Empire	1955	SSWSA
Gaines	Texaco	No. 1 Pence	Tr. 2, Lge. 313, Gaines C.S.L.	11,266	Texaco	1955	Texaco
Gaines	Texaco	No. 1 Anon Carter Foundation	Sec. 212, B.-G, CCSD&RGNG	11,229	Texaco	1955	Texaco
Gaines	Wrather	No. 1 Sawyer	Sec. 63, B.-H, D&W	13,184	Empire	1955	Texaco
Gaines	Texaco	No. 1 T. S. Riley	Sec. 423, B.-G, CCSD&RGNG	10,910	Texaco	1955	Texaco
Gaines	Shell	No. 1 Jones	Sec. 5, B.-A-8	12,701	Shell	1955	Shell
Gaines	Shell	No. 1 Hogan	Sec. 16, B.-A-28, P.S.L.	9,652	Shell	1952	Shell
Gaines	Stanolind	No. 1 Oil Dev. Co. "D"	Sec. 145, B.-G, WTRR	13,820	Empire	1955	Stanolind
Gaines	Union	No. 1-A E. H. Jones	Sec. 14, B.-A-7, P.S.L.	12,360	United	1952	Union
Gaines	Union	No. 1-A Nick Alley, Jr.	Sec. 22, B.-A-27	8,638	United	1955	Union
Gaines	J. C. Barnes	No. 1 S. W. Altman	Sec. 32, B.-H, D&WRR	12,935	Empire	1956	Atlantic
Gaines	Monterey Oil Co.	No. 41-58 Monterey Oil Dev. Co.	Sec. 58, B.-G, WTRR	13,370	SSC	1956	Monterey
Gaines	Humble	No. 1 Methodist Home	Sec. 8, B.-A-9, P.S.L.	11,942	Humble	1956	Humble
Galveston	Shell (offshore)	No. 1 Stract Tr. 249	State Tr. 249—Gulf of Mexico	7,225	Shell	1955	Shell
Galveston	Texas Eastern	No. 1 Oldham	2½ mi. NE of Arcadia		Schlumberger	1955	S.O.T.
Galveston	Phillips	No. 1-A Christensen	Pallas Love Sur. A-145	15,374			Phillips
Garza	Seaboard & Rep. Nat. Gas	No. 2-A O. S. Ranch	Sec. 3, HL&D Sur.	7,700	SSC	1955	Seaboard & Rep. Nat. G.
Garza	Jack Markham	No. 2 Slaughter	Sec. 1, B.-30, T-7N, TW&NG	9,050		1956	Stanolind
Glasscock	Shell	No. 1-A McDowell	Sec. 30, B.-34, T-2S, T&P	10,800	Magnolia	1956	Magnolia
Goliad	Humble	No. 1 Otto A. Neese	Maria Jesus de Leon Sur. A-22	5,678	Schlumberger	1956	Humble
Gonzales	Gulf Coast Leaseholds	No. 1 J. L. Johnson	Thos. P. Fowle Sur. A-219	8,018	Schlumberger	1955	Humble

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Gray	Shamrock	No. 1 Byrum	Sec. 47, B.-M-2, H&GN	13,051	Magnolia	1955	Magnolia
Gray	Phillips	No. 1 Troy "B"	Sec. 86, B.-M-2, H&GN	11,695			Phillips
Grayson	Pure	No. 1 Circle "F" Ranch	660' FN&EL Wm. Wells Sur.	4,450	Pure		Pure
Grayson	Howell-Holloway	No. 1 Anna Miller	Heydrick Co-ordinate K-7	9,450	Shell	1953	Shell
Grayson	Howell-Holloway	No. 1 Hutchinson	Heydrick Co-ordinate A-1	7,910	Shell	1952	Shell
Grayson	L. O. McMillan	No. 1 Blanton	Heydrick Co-ordinate J-5	6,796	Shell	1953	Shell
Grayson	Shell	No. 1 Cullums Est.	Heydrick Co-ordinate G-1	7,794	Shell	1953	Shell
Grayson	Star et al.	No. 1 Hodgin	W. B. Blundell Sur. A-116	10,500		1956	Stanolind
Hardeman	Shell	No. 1 Tabor	Heydrick Co-ordinate I-2	7,599	SSC	1955	Shell
Hartley	Clark Drilling	No. 1 Martin	Sec. 10, B-A-10, P.S.L.	8,000		1955	S.O.T.
Hartley	S.O.T.	No. Buzzard	Sec. 45, B.-"LE", G&M	8,185	Schlumberger	1955	S.O.T.
Hartley	Taylor	No. 1 Taylor	Sec. 26, B.-13, CSS			1955	S.O.T.
Hartley	Phillips & Kerr-McGee	No. 1-A Cattle	Sec. 18, B.-ITO, T&NO	9,100	SSC	1955	Kerr-McGee
Harris	Sun	No. 1 Matlage	M. Tigerion Sur. A-763	4,400	Schlumberger	1955	Sun
Harris	Sun	No. 2 Matlage	M. Tigerion Sur. A-763	5,210	Schlumberger	1955	Sun
Hemphill	Sun	No. 1-A Dale Nix	Sec. 90a, B-42, H&TC	11,141	Empire	1955	Stanolind
Henderson	Amerada	No. 1 Howard-Evans	Thomas Parmer Sur. A-782	8,997		1954	Stanolind
Hidalgo	Delhi-Taylor	No. 1 Renken Unit	Lot 12, Blk. 6, Hidalgo Canal Co.	9,880	Petty	1955	Delhi-Taylor
Hockley	Honolulu	No. 19-B Elwood	Sec. 32, B.-A, R. M. Thompson	11,760	SSC	1956	Honolulu
Hockley	S.O.T.	No. 1 W. C. Huffaker "2" Tr. 4	Sec. 1, B.-D, EL&RR	10,200		1954	S.O.T.
Houston	Magnolia	No. 1 Dan Hartt	John Forbes A-32	14,980	Magnolia	1956	Magnolia
Irion	C.S.O.	No. 1-AY University	Sec. 7, B.-43, U.L.S.	9,110	SSC	1955	C.S.O.
Irion	Sinclair	No. 1 S. H. Sugg	Sec. 83, B.-1, H&TC	7,600?		1955	Sinclair
Irion	Sinclair	No. 1 E. C. Sugg	Sec. 49, B.-14, H&TC	9,000?		1955	Sinclair
Irion	Sinclair	No. 1 L. Wilson	Sec. 87, B.-1, H&TC	8,570?		1955	Sinclair
Irion	Tucker	No. 1 A. A. Suggs	Sec. 5, B-2, H&TC	7,700		1955	Stanolind
Irion	Alvon Oil & Gas	No. 1 A. A. Suggs	Sec. 6, B.-6, H&TC	8,332		1955	Stanolind
Irion	Russell McGuire	No. 1 Sugg "B"	Chadwick Sur. No. 42	7,075		1956	Stanolind
Jackson	Magnolia	No. 417 W. Rank "A"	Ramon Musquiz Grant	15,405	Magnolia	1955	Magnolia
Johnson	Christie, Mitchell & Mitchell	No. 1 Peikoff	W. Hickman Sur. A-327	8,310			Phillips
Jefferson	Magnolia	No. 1 Texas Gulf Tract 10	Tract 10, High Island (offshore)	13,380	Magnolia	1955	Magnolia
Kimble	C.S.O.	No. 1 Nelson "B"	Sec. 56, TW&NG Sur.	3,826	Empire	1956	C.S.O.
Knox	Union-Duffy	No. 1 Beavers	Sec. 229, B.-44, H&TC	6,517	United	1953	Union
Lamb	Texas	No. 1 Chisholm	Lbr. 5, Lge. 657, SCL	9,700	United	1955	Honolulu
Leon	Sun	No. 1 Starkey	Thomas Toby A-888	9,000	Schlumberger	1955	Sun
Liberty	Amerada	No. 1 B. H. Willis Est.	Robt. Burrell Sur. Abst. 138	8,683	GRC	1955	Amerada
Liberty	Humble	No. 1 S. W. Hardin-3	1,225' NW Frazier No. 1	5,645	Schlumberger	1956	Humble
Lipscomb	Humble	No. 1 W. C. Merydith	Sec. 469, B.-43, H&TC	8,646	Humble	1956	Humble
Loving	Shell	No. 1 University 19-A	Sec. 18, B.-19, UTL	5,201	Magnolia	1955	Magnolia
Loving	Trico	No. 1 TXL	Sec. 13, B.-56, T-1, T&P	3,840	Empire	1955	Stanolind
Loving	Ibex	No. 1 Rio Bravo	Sec. 75, B.-33, H&TC	4,332		1955	Stanolind
Lynn	Texaco	No. 1-A Covert	Sec. 21, B.-0, HOBRR	11,890			Texaco
Matagorda	Magnolia	No. 2 Hawkins	Sol Willimas A-106	15,130	Magnolia	1956	Magnolia
Maverick	Conoco	No. 3 Chittim	Sec. 7, B.-6, I&GNRR	7,418	Schlumberger	1955	Conoco
Maverick	Humble	No. 1 Bandera CSL	Bandera CSL Sue. 231, A-37	13,518	Humble	1956	Humble
Menard	Allison Oil	No. 1-A Volkman	Sec. 112, Owen Baker Sur.	4,000	SSC	1955	Amerada
Menard	Humble	No. 1 Mary E. Rogers	Sec. 15, B.-2, Twng. Sur.	5,332	Schlumberger	1956	Humble
Midland	Forest & C.S.O.	No. 5 "B-1" Roberts	Sec. 4, B.-41, T-3S, T&P	13,020	Dawson	1955	Forest
Midland	Gulf	No. 1 C. E. Scharbauer	Sec. 34, B.-40, T-1S, T&P	13,402			Gulf
Mitchell	Gulf	No. 1 Chappell	Sec. 20, B.-18, SPRR	7,865	Empire	1955	Gulf
Mitchell	Stanolind	No. 1 Richard	Sec. 64, B.-25, T&P	7,508	Empire	1955	Stanolind
Nacogdoches	Humble	No. 1 Mast	8,450' FSL, 1,200' FEL Sanchez Sur.	10,014		1955	Stanolind
Neuces	Humble	No. 1 Gulf of Mex. St. Tr. 772	St. Tr. 772, Offshore	9,948	Schlumberger	1956	Humble
Neuces	Humble	No. FF-2 E. Flour Bluff	St. Tr. 51, Laguna Madre Bay	10,007	Schlumberger	1956	Humble
Nolan	Hunt	No. 1 C. E. Boyd	Sec. 59, B.-X, T&P	6,643	Empire	1955	Hunt
Nolan	Norsworthy	No. 1 Compton	Sec. 52, B.-1-A, H&TC	7,145	Empire	1955	Stanolind
Nolan	Honolulu	No. 1 Dennis	Sec. 312, B.-64, H&TC	6,780	United	1955	Honolulu

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Nolan	Honolulu	No. 1 Spires	Sec. 124, B.-1-A, H&TC	7,515	United	1955	Honolulu
Ochiltree	Honolulu	No. 1 Chunn	Sec. 76, B.-4-T, T&NO Sur.	8,822	United	1956	Honolulu
Ochiltree	Union	No. 1 Hellenbein	Sec. 936, B.-43, H&TC	9,140	Magnolia	1955	Magnolia
Ochiltree	Texas	No. 1 Barlow	Sec. 929, B.-43, H&TC	8,695	Magnolia	1955	Magnolia
Ochiltree	Magnolia	No. 1 Parnell	Sec. 494, B.-43, H&TC	9,690	Magnolia	1955	Magnolia
Pecos	Conoco	No. 1 Noelke	Sec. 1, B.-193, TM&RR	10,320	Conoco	1956	Conoco
Pecos	Conoco	18-4 University No. 1	Sec. 4, B.-18, UL	7,320	Conoco	1956	Conoco
Pecos	Lang & Unger	No. 1 White	Sec. 16, B.-9, H&GN	7,050	Schlumberger	1956	
Pecos	Kennedy-Chambers-Union	No. 1-A Sylvester	Sec. 48, H&GN	5,412	Schlumberger	1956	Union Gulf
Pecos	Hunt	No. 47 Elsinore	Sec. 21, B.-B, GC&SF	18,635	Empire		
Pecos	Magnolia	No. 1 Emert	Sec. 20, B.-48, T-8S, T&P	5,989	SSC	1955	Magnolia
Pecos	British-American	No. 1 Hines	Sec. 11, B.-112, TCRR	10,685	SSC	1955	Brit. Amer.
Pecos	S.O.T.	No. 3 Cannon	Sec. 18, B.-C-3, EL&RR	9,830	SSC	1955	Sohio
Pecos	Forest	No. 1 White & Baker Blk. 2	Sec. 50, B.-194, GC&SF	8,216	United	1955	Atlantic
Pecos	Vega	No. 1 Rayner	Sec. 68, B.-10, H&GN	4,890		1954	Stanolind
Pecos	Blackwood-Nichols	No. 1 Slaughter	Sec. 29, B.-129, T&ST	10,340		1954	Stanolind
Pecos	Tidewater	No. 1 White & Baker	Sec. 23, B.-Z, TC&RR	10,029	SSC	1956	Tidewater
Randall	Hunt	No. 1 Carruth	Sec. 180, B.-6, I&GN	8,480	Magnolia	1955	Magnolia
Reagan	Phillips-Southern Royalty	No. 1 Zulette	Sec. 10, GC&SF	10,965			Phillips
Reagan	Forest	No. 1 Continental Univ.	Sec. 24, B.-2, ULS	11,045	Dawson	1955	Forest
Reagan	Cosden	No. 1-20 University	Sec. 20, B.-2, ULS	10,765	Texaco	1955	Texaco
Reagan	Texaco	No. 1 W. H. Dixon	Andrews Roach	12,220	Texaco	1955	Texaco
Reagan	Texaco	No. 1 Becton	Sec. 1, Whatley Sur.	10,715	Empire	1955	Texaco
Reagan	Texaco	No. 1 Young	Sec. 1, B.-A-170, GC&SF RR	9,294	Texaco	1955	Texaco
Reagan	Stanolind	No. 1 University "BS"	Sec. 29, B.-58, Univ. Lds.	10,914	Empire	1955	Stanolind
Reagan	Phillips	No. 2 Zulette	Sec. 11, B.-C, GC&SF	10,555		1956	Phillips
Reeves	C. Ikins & Keljikan	C. L. Rampy et al. No. 1	Sec. 238, B.-13, H&GN	5,250	Empire	1956	Atlantic
Reeves	Amer. Trading & Prod. Co.	No. 1 Lyster	Sec. 2, B.-51, T-7, T&P	5,700		1955	Stanolind
Reeves	Jay Simmons	No. 1 Anthony & Tubb	Sec. 7, B.-C-4, PSL	5,244		1955	Stanolind
Refugio	Shell	No. 2 M. V. O'Connor Tr. 12	W. M. Wilson A-135	6,500	Schlumberger	1955	Shell
Refugio	Humble	No. 1 L. W. O'Conner Trust Est.	J. S. Brooks Sur., 5 mi. SE Refugio	8,900	Schlumberger	1956	Humble
Roberts	Phillips	No. 2 Gay	Sec. 201, B.-M-2, BS&F	9,992	SSC	1955	Phillips
Schleicher	Conoco	No. 1 Moore	Sec. 29, B.-A, GC&SF	8,402	Schlumberger	1955	Conoco
Scurry	Stanolind	No. 1 South	Sec. 72, B-2, H&TC	7,400	Empire	1955	Stanolind
Scurry	Phillips	No. 1-A Whatley	Sec. 405, B.-97, H&TC	8,485	SSC	1955	Phillips
Shelby	Stanolind	No. 1-A Parker	C. C. Tutt Sur. A-726	10,970		1956	Stanolind
Sherman	Evans	No. 1-A Freeman	Sec. 47, B.-2, GH&H	5,456		1956	Phillips
Smith	Sun	No. 1 Elliot	Thomas Payne 1F 763	13,200	Schlumberger	1956	Sun
Smith	Humble	No. 1 Emmett A. Humble	40 A. Tract, 5 mi. W. Taylor	10,721	Schlumberger	1956	Humble
Starr	Sun	No. 7 Coates	CCSD&RGNG Sur. 515	8,700	Schlumberger	1955	Sun
Sterling	Conoco	No. 1-A French	Sec. 97, B.-6, H&TC	8,100	Schlumberger	1955	Conoco
Sterling	Ultra Oil Co.	No. 1 Sugg	Sec. 9, B.-A, GC&SF				
Stonewall	Payne & Johnston	No. 1 Metcalf	Sec. 171, B.-"D", H&TC	6,355	Empire	1955	Stanolind
Stonewall	Amer. Trading & Prod.	No. 1 Tony Lindhorst	Sec. 354, B.-D, H&TC	6,856	SSC	1955	Amer. Trad. & Prod.
Stonewall	Texas Crude et al.	No. 1-7 T. A. Jean	Sec. 7, B.-U, T&P	6,309		1955	Stanolind
Stonewall	Sunray Mid-Cortinent	No. 1 Bilberry	Sec. 74, B.-D, H&TC	6,135	SSC	1956	Sunray Mid-Cont.
Swisher	Sinclair	No. 1 Savage	Sec. 34, B.-B-4, AB&M			1955	Sinclair
Taylor	A. W. Cherry	No. 1 Christian	Sec. 104, B.-64, H&TC	6,128		1954	Stanolind
Terry	Phillips	No. 1 John "E"	Sec. 135, B.-D-11, C&MRR	13,462			Phillips
Terry	Texaco	No. 1 L. D. Spradling	Sec. 115, B.-D-11, C&MRR	12,744	Texaco	1955	Texaco
Terry	Ada	No. 1 Akers	Sec. 10, B.-M, PSL	9,740	Empire	1955	Texaco
Terry	Williamson	No. 1-A Coline	Sec. 58, B.-DD, J. H. Gibson	12,040	United	1955	Stanolind
Terry	Tri-Service	No. 1 Mitchell	Sec. 57, B.-D-11, C&MRR	12,500	Empire	1955	Stanolind
Terry	Honolulu	No. 19-B Ellington	Sec. 19, B.-K, PSL	13,350	United	1955	
Terry	Honolulu	No. 1 Covington "B"	Sec. 5, B.-D-14, C&MRR	12,285	United	1955	Honolulu

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
Tom Green	Union	No. 1 E. G. Wilde	Sec. 57, Dist. 11, SP&RR	5,792	Schlumberger	1955	Union
Tom Green	Norsworthy	No. 4 Robertson	Sec. 18, B.-22, H&TC	6,115	Schlumberger	1955	Shell
Tom Green	Phillips	No. 1 Winfrid	Presidio Irr. Co. Sur. No. 3	7,417	Schlumberger	1955	S.O.T.
Tom Green	Scherck & Wahlenmaier	No. 1 E. H. Jones	Sec. 932, Fisher & Miller Sur.			1955	Sinclair
Tom Green	Scherck & Wahlenmrier	No. 1 D&N McGowan	Sur. 9, J. Stooksberry Sur.			1955	Sinclair
Tom Green	Dorrance	No. 1—AX Jackson	Sec. 99				
Upton	Phillips	No. 1 University "H"	Sec. 5, B.-15, ULS	5,070	Schlumberger	1955	
Upton	Gulf	No. 1 McElroy Ranch "G"	Sec. 2, B.-C$\frac{1}{2}$, McElroy Sur.	10,600			Phillips
Upton	Wilshire	No. 43-31 Peck	Sec. 31, B.-42, T-4S, T&P	12,122	Empire		Gulf
Upton	Humble	No. D-1 Rosa H. Barnett	Sec. 83, B.-Y, GC&SF RR	13,575	United	1955	Wilshire
Upton	Hamon	No. 1 University "D"	Sec. 1, B.-58, UTL	11,848	Humble	1955	Humble
Upton	Ohio	No. 1 H. L. Cox "A"	Sec. 21, B.B.-, HF&WT	11,460	Empire	1955	Gulf
Upton	Williamson & Roden	No. 1 Windham	Sec. 140, B.-E, CCSD&RGNG	11,036	United	1955	Atlantic
Upton	Hunt	No. 1 Windham	Sec. 16, B.-2, MK&T			1955	Sinclair
Upton	Magnolia	No. 1 University "I"	Sec. 15, B.-3, UTL			1955	Sinclair
Upton	Texaco	No. 1 Shirk "A"	Sec. 23, B.-2, MK&T	12,250	Magnolia	1956	Magnolia
Upton	Sunray Mid-Continent	No. 1 Hazel Neal	Sec. 75, B.-C, CCSD&RGNG	11,050			Texaco
Upton	Sunray Mid-Continent	No. 1-A Hazel Neal	Sec. 70, B.-C, CCSD&RGNG	13,538	SSC	1956	Sunray Mid-Cont.
Upton	Monsanto Chem. Co.	No. 1 Kay	Sec. 1, GC&SF	13,400	SSC	1956	Sunray Mid-Cont.
Val Verde	Magnolia	No. 1 Morrison	Sec. 10, B, Q-4, TCRR	10,470	Empire	1956	Atlantic
Ward	Argo	No. 1 Royal Est.	Sec. 193, B.-34, H&TC	15,115	Magnolia	1955	Magnolia
Ward	Magnolia	No. 3 University "B Unit"	Sec. 6, B.-18, UTL	5,000	Schlumberger	1955	Shell
Ward	Magnolia	No. 4 University "B Unit"	Sec. 34, B.-17, UTL	5,025	Magnolia	1955	Magnolia
Ward	British-American	No. 1 Marsten	Sec. 10, B.-B-19, PSL	5,180	SSC	1955	Magnolia
Ward	Stanolind	No. 1 Blair	Sec. 5, B.-32, H&TC	10,545	Magnolia	1955	Magnolia
Ward	Shell	No. 1 University 17-J	Sec. 17, B.-17, UTL	7,430		1953	Stanolind
Webb	H. R. Smith et al.	No. 1 J. M. Martin	H. H. Nelson No. 87, A-2798 Sur.	5,090	Magnolia	1956	Magnolia
Webb	Texaco	No. 1 Bruni	J. V. Borego Grant	12,000	Petty	1955	Shell
Wheeler	Sunray Mid-Continent	No. 1-A Britt	Sec. 3, B.-1, Brooks & Burleson	7,500			Texaco
Wilbarger	Fair Foundation	No. 1 W. T. Waggoner Est.	Sec. 1, B.-2, H&TC RR	7,175	SSC	1956	Sunray
Wilbarger	Sunray Mid-Continent	No. 1 Mock Ranch	Sec. 25, B.-11, H&TC	5,510	Empire	1955	Pure
Winkler	Magnolia	No. 25-E State-Walton	Sec. 5, B.-B-3, PSL	6,488	OGC	1955	Sunray Mid-Cont.
Winkler	Tidewater	No. 1 Earl Vest	Sec. 15, B.-B-8, PSL	10,664	Magnolia	1955	Mangolia
Winkler	Stanolind	No. 7 Cowden	Sec. 37, B.-B-5, PSL	11,468	SSC	1955	Tidewater
Winkler	Shell-Phillips	No. 1 McCabe	Sec. 36, B.-B-5, PSL	11,515	Empire	1955	Stanolind
Winkler	Lowe	No. 1-H University	Sec. 48, B.-21, Univ.	11,598	Magnolia	1955	Magnolia
Winkler	Sunray Mid-Continent	No. 5 Hill	Sec. 19, B.-B-11, PSL	3,160	Magnolia	1956	Magnolia
Winkler	S.O.T.	No. 1 Lovett	Sec. 14, B.-B-3, PSL	12,138	SSC	1956	Sunray Mid-Cont.
Winkler	Humble	No. 1 Waddell Bros.	Sec. 2, B.-40, PSL	10,640	Magnolia	1956	Magnolia
Wood	Stanolind	No. 1 Pevoto	Sara McDonald Sur. A-382	11,372	Humble	1956	Humble
Yoakum	Plymouth	No. 1 Cox	Sec. 523, B.-D, J. H. Gibson	10,320		1955	Stanolind
Yoakum	Stanolind	No. 1 Williams	Sec. 619, B.-"D", Gibson	11,870	United	1956	Plymouth
Yoakum	Stanolind	No. 1 Lott	Sec. 248, B.-"D", Gibson	13,570	Empire	1955	Stanolind
				12,775	Empire & Schlumberger	1955	Stanolind
Yoakum	Hunt	No. 1 Googins	Sec. 191, B.-D, J. H. Gibson	12,513		1954	Stanolind
Yoakum	Murchison & Mallory	No. 1 Southland Royalty	Sec. 84, B.-D, J. H. Gibson	12,222		1955	Stanolind
Yoakum	Humble	No. 8 Annie Armstrong	Sec. 869, B.-D, J. H. Gibson	10,800	Humble	1956	Humble
Young	Texaco	No. 1 Irene McPherson	B.-A-1, I. D. Aud Sur.	4,674	Petty	1955	Texaco
			STATE OF UTAH				
Box Elder	Gulf	No. 1 Williams Fed.	Sec. 11, 6N-16W	2,850	Gulf	1954	Gulf
San Juan	Shell-Conoco	No. 1 Hovenweep	5, 40S-26E	7,520	Shell	1956	Shell-Conoco
San Juan	Gulf	No. 2 Coal Bed Canyon Unit	20, 35S-26E	8,400	Gulf	1956	RMSWSA
San Juan	Texaco	No. 1 Navajo	7, 40W-26E	7,500	SSC	1956	Gulf
San Juan	Carter	No. 1 Govt. Arrowhead	31, 39S-24E	7,000	SSC	1956	Carter

County	Company	Lease	Location	Survey Depth	Shot by	Date	Sponsored by
San Juan	Shell	Desert Creek No. 26-36	36, 41S -23E	5,595	Shell	1956	Shell
San Juan	Shell	Butte No. 1	33, 42S -22E	5,962	Shell	1956	Shell
San Juan	Shell	White Nesa No. 1	0, 43S -24E	6,015	Shell	1956	Shell
San Juan	Superior	Navajo Tribal No. 1-28	28, 41S -26E	6,150	Shell	1956	Shell
Unitah	Gulf	No. 1 Ute Federal	12, 4S -22E	6,673	Gulf	1954	Gulf
Unitah	Gulf-Woodward	McCook Ridge No. 1	25, 13S -23E	6,025	Gulf	1954	Gulf
Unitah	Phillips	Two Waters No. 1	22, 14S -25E	8,800	Gulf	1955	Gulf
Unitah	Gulf	No. 2 Brennan Fed.	18, 7S -21E	7,185	SSC	1956	Gulf
Unitah	El Paso	No. 2 Southman Canyon	11, 10S -23E	5,000	SSC	1955	El Paso
Unitah	Phillips	No. 1-B Watson	34, 9S -25E	11,375	Gulf	1955	RMSWSA
Unitah	Standard	No. 32 Red Wash Unit	22, 7S -22E	11,105	SSC	1955	Standard
Wayne	Carter	No. 1 Nequois Arch	5, 27S -14E	5,920	SSC	1956	RMSWSA
			STATE OF WASHINGTON				
Callam	Standard	No. 2 Dalton Pettit		3,167	GSI	1955	CWVSG
Grays Harbor	Conoco	No. 1 E. A. Sims-Oil Royalty Co.	Sec. 31, 19N- 8W	3,150	GSI	1954	CWVSG
Grays Harbor	Conoco	No. 1 Pitchford-McClymont	4, 15N- 8W	3,750	Ray	1955	CWVSG
			STATE OF WYOMING				
Big Horn	Carter	No. 1 Govt. Horse Gulch	17, 50N- 91W	3,980	SSC	1956	RMSWSA
Campbell	Cranlyn Expl.	No. 1 Government	33, 54N- 78W	9,070	SSC	1955	Gulf & Sunray Mid-Cont.
Campbell	Rochelle	No. 1 Government	1, 43N- 69W	10,650	SSC	1955	RMSWSA
Carbon	Vaugh Prod.	No. 1 Dad Unit	11, 15N- 91W	10,190	Mtn. Geo.	1952	RMSWSA
Converse	Mobil	Carey-Bixby No. T-73-24-P	24, 33N- 75W	7,740	SSC	1956	RMSWSA
Crook	Gulf	No. 1 Little Missouri Fed.	9, 55N- 67W	4,046	SSC	1956	RMSWSA
Fremont	Conoco	No. 1 Tribal	20, 2N- 1W	3,485	SSC	1956	Conoco
Fremont	Sohio	South Sand Draw Unit No. 4	30, 32N- 95W	8,800	SSC	1955	RMSWSA
Fremont	Calco	No. 1 Govt. Languuth	0, 42N-107W	5,000	SSC	1956	Calco
Goshen	G. H. Anderson	No. 1 Hunter	22, 19N- 62W	7,966	SSC	1956	Plymouth
Goshen	F. R. Anderson	No. 24-5 Jobe	5, 21N- 61W	7,085	SSC	1956	RMSWSA
Jackson	Carter	No. 1 Govt. McDonnold	4, 10N- 80W	7,800	SSC	1956	Carter
Johnson	Conoco	No. 149E Meadow Creek Unit	14, 41N- 78W	9,043	SSC	1956	Conoco
Johnson	Conoco	No. 116 Sussex	23, 42N- 78W	9,250	SSC	1956	RMSWSA
Johnson	Shell	South Crazy Woman Unit No. 1	5, 46N- 81W	12,850	SSC	1956	RMSWSA
Johnson	Pure	No. 1 Schoonover	20, 48N- 76W	13,800	United	1952	RMSWSA
Laramie	Progress Frontier	Wyo. Hereford Ranch No. 1	11, 13N- 65W	9,485	Shell	1953	Shell
Natrona	Conoco	No. 1 Radreville	30, 35N- 89W	6,831	SSC	1955	Conoco
Natrona	Chicago Corp. & Rep. Nat. Gas	No. 2-C Govt. Tyson	2, 31N- 84W	5,486	SSC	1955	RMSWSA
Natrona	Shell	No. 1 Govt. Hill	31, 40N- 80W	4,060	SSC	1955	Shell
Park	Stanolind	No. 1 Government	31, 57N- 98W	7,360	SSC	1956	RMSWSA
Park	Carter	No. 13 Johnson-Watson	8, 57N- 99W	9,067	SSC	1956	Carter
Sheridan	Shell	No. 1 G. Dempie	22, 55N- 85W	11,348	SSC	1955	RMSWSA
Sheridan	Shell-McDermott	No. 1 Buszkiewic	30, 58N- 84W	5,900	SSC	1955	Shell
Sheridan	Shell	No. 1 Govt. Wamsley	13, 57N- 83W	9,740	SSC	1955	Shell
Sheridan	Pure	No. 1 Halvey	21, 56N- 83W	6,990	Pure	1955	Pure
Sublette	Phillips	No. 1 Sublette	21, 33N-111W	10,400	SSC	1955	Phillips
Sweetwater	El Paso Nat. Gas	No. 1 Morrow Creek	29, 25N-103W	9,304	SGC	1954	RMSWSA
Sweetwater	Carter	No. 1 Murphy	17, 26N- 94W	9,570	SSC	1956	Carter
Sweetwater	Gulf	Indian Gap Unit No. 1	1, 23N-104W	9,960	Gulf	1955	RMSWSA
Sweetwater	California	Spring Branch Unit No. 1	26, 13N-111W	7,550	Western	1952	California
Sweetwater	C.S.O.	Rock Springs Unit No. 1	7, 17N-105W	9,310	General	1956	C.S.O.
Washakie	Gulf	No. 1 Holland	14, 45N- 93W	10,236	Gulf	1953	Gulf
Washakie	Phillips	No. 1 Mesa "A"	27, 46N- 96W	13,000	SSC	1956	Phillips

FOREIGN COUNTRIES

CANADA

County	*Company*	*Lease*	*Location*	*Survey Depth*	*Shot by*	*Date*	*Sponsored by*
Alberta	Can. Superior	Can. Superior Rausch No. 1	Lsd. 12, Sec. 21, T-44, R-27, W4M	7,500	Delta	1952	Cal. Stan.
Alberta	Cal. Stan.	C. S. Edgerton Prov. No. 64-24	6, 24, 45, 4, W4M	2,310	CEC	1946	Cal. Stan.
Alberta	Pacific Petr.	C. S. Pan Western West Edmonton No. 1	14, 21, 52, 25, W4M	5,602	GSI	1949	Cal. Stan.
Alberta	Cleary Oil	C. S. Cleary Kelsey No. 7-15	7, 15, 44, 18, W4M	4,940	SSC	1955	Cal. Stan.
Alberta	Cal. Stan.	C. S. Ferrybank	2, 8, 44, 27, W4M	7,822	SSC	1955	Cal. Stan.
Alberta	Cleary Oil	Cleary-C. S. Ferrybank No. 11-20	11, 20, 44, 27, W4M	7,521	SSC	1956	Cal. Stan.
Alberta	Cal. Stan.	C. S. Spotted Lake No. 3-15	3, 15, 41, 22, W4M	6,440	GSI	1950	Cal. Stan.
Alberta	Cal. Stan.	C. S. Chigwell No. 11-18	11, 18, 41, 24, W4M	6,885	Western	1952	Cal. Stan.
Alberta	Cal. Stan.	C. S. South Morningside No. 14-20	14, 20, 41, 27, W4M	9,062	United	1955	Cal. Stan.
Alberta	Cal. Stan.	C. S. Princess C.P.R. 76-23A	12, 23, 20, 12, W4M	3,904	GSI	1945	Cal. Stan.
Alberta	Cal. Stan.	C. S. Millicent C.P.R. No. 1	13, 17, 20, 13, W4M	4,135	GSI	1945	Cal. Stan.
Alberta	Cal. Stan.	C. S. Joffre No. 11-33	11, 33, 38, 26, W4M	5,270	SSC	1955	Cal. Stan.
Alberta	Amurex Oil Dev.	Rainy Hills Synd No. 1	6, 34, 19, 10, W4M	3,897	GSI	1946	Cal. Stan.
Alberta	Empire Pete.	Empire Pacific No. 2	16, 22, 19, 12, W4M	4,150	GSI	1945	Cal. Stan.
Alberta	Cal. Stan.	C. S. Patricia C.P.R. No. 1	4, 6, 20, 12, W4M	4,121	Tucker	1946	Cal. Stan.
Alberta	Cal. Stan.	C. S. Irvine Prov. No. 28-32	16, 32, 11, 2, W4M	3,285	GSI	1946	Cal. Stan.
Alberta	Cal. Stan.	C. S. Parkland No. 4-12	4, 12, 15, 27, W4M	8,780	SSC	1955	Cal. Stan.
Alberta	Cal. Stan.	C. S. Bantry C.P.R. No. 75-8	12, 8, 17, 13, W4M	3,874	GSI	1948	Cal. Stan.
Alberta	Sun	3-35 Pine	3, 35, 31, 22, W4M	6,735	SSC	1954	Sun
Alberta	Sun	15-14 Sun "A" Pine	15, 14, 31, 22, W4M	6,776	SSC	1955	Sun
Alberta	Cal. Stan.	C. S. Foremost Prov. No. 4	2, 28, 5, 11, W4M	4,054	GSI	1946	Cal. Stan.
Alberta	Cal. Stan.	C. S. Shekilie River	9, 26, 120, 11, W6M	7,005	GSI	1954	Cal. Stan.
Alberta	H.B.O.C.	Twin Dome No. 1	16, 8, 22, 1, W5M	9,537	SSC	1956	H.B.O.G.
Alberta	H.B.O.G.	N. W. Cessford No. 1	6, 30, 25, 15, W4M	3,908	SSC	1956	H.B.O.C.
Alberta	Cal. Stan.	C. S. Little Cadotte Lake	2, 15, 85, 16, W5M	5,894	Chevron	1956	Cal. Stan.
Alberta	Cal. Stan.	C. S. Smoky River	13, 20, 75, 2, W6M	9,603	Western	1953	Cal. Stan.
Alberta	Cal. Stan.	C. S. Steen River No. 2-22	2, 22, 117, 5, W6M	6,761	GSI	1953	Cal. Stan.
Alberta	Cal. Stan.	C. S. Cynthia No. 8-11	8, 11, 49, 12, W5M	6,150	SSC	1955	Cal. Stan.
Alberta	Cal. Stan.	C. S. Cynthia No. 4-25	4, 25, 50, 12, W5M	5,950	SSC	1955	Cal. Stan.
Alberta	Cal. Stan.	C. S. Gulf Kaybob No. 5-35	5, 35, 62, 18, W5M	11,294	SSC	1955	Cal. Stan.
Alberta	Cal. Stan.	C. S. Homeglen No. 3-29	3, 29, 43, 1, W5M	6,900	Delta	1953	Cal. Stan.
Alberta	Cal. Stan.	C. S. South Westerose No. 15-11	15, 11, 45, 1, W5M	7,700	Delta	1953	Cal. Stan.
Alberta	New Ranchmen's	Ranchmen's Territory Fireland No. 1	1, 13, 46, 1, W5M	7,476	Delta	1953	Cal. Stan.
Alberta	Cal. Stan.	C. S. East Gilby No. 4-5	4, 5, 41, 2, W5M	11,550	SSC	1954	Cal. Stan.
Alberta	Cal. Stan.	C. S. Forshee No. 10-4	10, 4, 42, 1, W5M	8,610	Subsurface	1953	Cal. Stan.
Alberta	Cal. Stan.	C. S. Rimbey No. 11-3	11, 3, 42, 2, W5M	7,894	Beaver	1953	Cal. Stan.
Alberta	Cal. Stan.	C. S. Sylvan Lake No. 5-16	5, 16, 38, 2, W5M	9,400	Delta	1955	Cal. Stan.
Alberta	Cal. Stan.	C. S. South Gilby No. 10-7	10, 7, 40, 2, W5M	7,511	SSC	1954	Cal. Stan.
Alberta	Cal. Stan.	C. S. Bentley No. 10-11	10, 11, 40, 2, W5M	9,118	Subsurface	1953	Cal. Stan.
Alberta	Cal. Stan.	C. S. Narrow Lake No. 1	5, 19, 65, 24, W4M	4,750	Delta	1952	Cal. Stan.
Alberta	Cal. Stan.	C. S. Francis Lake No. 1	4, 26, 66, 25, W4M	4,829	Geoprosco	1952	Cal. Stan.
Alberta	Cal. Stan.	C. S. West Calling Lake No. 16-36	16, 36, 71, 24, W4M	5,070	SSC	1955	Cal. Stan.
Alberta	New Superior-H.B.O.G.	Garrington No. 11-33	11, 33, 34, 4, W5M	10,366	National	1954	H.B.O.G.
Alberta	H.B.O.G.-Gulf-Superior	Evarts No. 1	3, 15, 38, 3, W5M	9,351	National	1953	H.B.O.G.-Gulf-Super.
Alberta	H.B.O.G.-Richfield	Edson No. 1	11, 33, 51, 19, W5M	13,467	National	1953	H.B.O.G.
Alberta	H.B.O.G.-Stanolind-Fina	Beaver Creek No. 1	1, 32, 56, 19, W5M	13,729	SSC	1956	H.B.O.G.-Stan.-Fina
Alberta	Fina-Stanolind-H.B.O.G.	Windfall No. 12-36	12, 36, 59, 15, W5M	10,930	SSC	1955	Fina-Stan.-H.B.O.G.

County	*Company*	*Lease*	*Location*	*Survey Depth*	*Shot by*	*Date*	*Sponsored by*
Alberta	H.B.O.G.-Union-Liberal	Debolt No. 1	11, 6, 68, 2, W6M	8,290	SSC	1956	H.B.O.G.-Union
Alberta	H.B.O.G.-Union-Liberal	Liberal No. 12-27	12, 27, 68, 21, W5M	9,610	GSI	1954	H.B.O.G.-Union
Alberta	H.B.O.G.-Union-Liberal-Gulf	Gulf No. 1	3, 5, 68, 22, W5M	10,736	SSC	1955	H.B.O.G.-Union-Gulf
Alberta	H.B.O.G.-Union	East Eaglesham No. 1	11, 35, 78, 25, W5M	8,072	SSC	1956	H.B.O.G.-Union
British Columbia	H.B.O.G.-Brit. Am.-Union	Hilligan Creek No. 1	70°03'55" N Lat 120°22'07" W Long	5,985	GSI	1955	H.B.O.G.-B.A.-Union
Manitoba	Trident Drilling	Trident Fontana No. 2-10	2, 10, 11, 25, W1M	2,100	SSC	1955	Cal. Stan.
Manitoba	Cal. Stan.	C. S. Kirkella No. 13-4	13, 4, 12, 29, W1M	2,485	SSC	1955	Cal. Stan.
Manitoba	Cleary Oil	Cleary Flossie Lake No. 10-21	10, 21, 1, 23, W1M	4,089	Western	1956	Cal. Stan.
Manitoba	Cal. Stan.	C. S. Whitewater No. 15-36	15, 36, 3, 22, W1M	4,088	United	1954	Cal. Stan.
Manitoba	U. S. Smelting	U. S. Smelting Alston No. 1-35	1, 35, 6, 23, W1M	2,479	United	1955	Cal. Stan.
Manitoba	McArty & Coleman	McArty & Coleman Janz No. 16-20	16, 20, 7, 21, W1M	2,131	United	1954	Cal. Stan.
Manitoba	Crawford E. Smith	C. E. Smith Agnew No. 13-17	13, 27, 8, 8, W1M	2,750	United	1955	Cal. Stan.
Manitoba	Cal. Stan.	C. S. West Butler No. 1-31	1, 31, 9, 29, W1M	3,020	United	1955	Cal. Stan.
Sask.	Cal. Stan.	C. S. Bannock No. 15-5	15, 5, 46, 9, W2M	2,529	United	1955	Cal. Stan.
Sask.	Cal. Stan.	C. S. Laird No. 16-6	16, 16, 43, 4, W3M	3,747	SSC	1956	Cal. Stan.
Sask.	Brit. Amer.	Husky Phillips Colmer No. 5-28	5, 28, 22, 7, W2M	2,339	United	1954	Cal. Stan.
Sask.	Cal. Stan.	Tidewater Hubbard No. 1-28	1, 28, 24, 10, W2M	4,470	SSC	1955	Cal. Stan.
Sask.	Cal. Stan.	C. S.-Can. Gulf Leonard	13, 3, 42, 26, W2M	3,219	United	1956	Cal. Stan.
Sask.	Cal. Stan.	C. S. Red Jacket No. 10-5	10, 5, 15, 31, W1M	2,884	Western	1954	Cal. Stan.
Sask.	Tidewater	Tidewater Cutarm No. 1	1, 4, 20, 32, W1M	4,675	United	1955	Cal. Stan.
Sask.	Cal. Stan.	C. S. Burrows No. 2-34	2, 34, 16, 1, W2M	2,780	Western	1954	Cal. Stan.
		VENEZUELA					
Anzoátegui	Socony Mobil	No. 5R La Ceibita	Dist. of Freites N. 203, 517 E. 555, 260	12,717	SSC	1956	Socony Mobil
Anzoátegui	Socony Mobil	No. 52R Araibel	Dist. of Freites N. 190, 184 E. 557, 049	11,864	SSC	1955	Socony Mobil
Anzoátegui	Socony Mobil	No. 52R Mata	Dist. of Freites N. 199, 092 E. 570, 068	12,216	SSC	1955	Socony Mobil
Anzoátegui	Socony Mobil	No. 54R Mata	Dist. of Freites N. 190, 090 E. 566, 835	12,272	SSC	1955	Socony Mobil
Anzoátegui	Socony Mobil	No. 49 Guario	Dist. of Freites N. 222, 094 E. 529, 322	8,942	SSC	1956	Socony Mobil
Anzoátegui	Socony Mobil	No. 5 Guario	Dist. of Freites N. 222, 726 E. 531, 586	10,014	SSC	1956	Socony Mobil
Anzoátegui	Socony Mobil	No. 19 N. Oscurote	Dist. of Freites N. 189, 801 E. 582, 560	10,267	SSC	1955	Socony Mobil
Anzoátegui	Socony Mobil	No. 23 N. Oscurote	Dist. of Freites N. 189, 490 E. 583, 135	10,751	SSC	1955	Socony Mobil
Anzoátegui	Socony Mobil	No. 1 Playa	Dist. of Freites N. 206, 294 E. 532, 640	12,169	SSC	1955	Socony Mobil
Barinas	Socony Mobil	No. 10 Silvestre	Dist. of Barinas N. 104, 692 W. 92, 570	9,868	SSC	1955	Socony Mobil
Barinas	Socony Mobil	No. 11 Silvestre	Dist. of Barinas N. 104, 125 W. 90, 600	9,762	SSC	1955	Socony Mobil
Barinas	Socony Mobil	No. 13 Silvestre	Dist. of Barinas N. 103, 200 W. 89, 600	9,746	SSC	1956	Socony Mobil
		REVISIONS & CORRECTIONS					
		(corrections are in italics)					
		STATE OF COLORADO					
Arapohoe	Warren	No. 1 Hart	Sec. 34, 4S-62W	7,682	Carter	1952	*Carter*
		STATE OF MONTANA					
Rosebud	Cosden Expl.	No. 1 Nefsy-Thompson	Sec. 34, 11N-42E	8,854	Rayflex	1953	*RMSWSA*
		STATE OF OKLAHOMA					
Carter	*Seaboard*	No. 3 C. R. Smith	Sec. 19, 3S- 1E	12,150	Rayflex	1954	Seaboard
Cleveland	Conoco	No. 1 Brendle	15, 8N- 1W	7,210	SSC	1955	*Conoco & Pure*
Garvin	Vickers	*No. 2* Sunray-Crawford	31, 3N- 3W	10,023	OGC	1955	Sunray
Garvin	Conoco	No. 4 Rose Vose 5	5, 2N- 3W	9,629	SSC	1954	*Carter & Conoco*
		STATE OF WYOMING					
Campbell	Gulf	No. 1 C. H. Davis	Sec. 34, 51N-72W	10,860	Gulf	1952	*Gulf*

DEPARTMENTS

PATENTS

O. F. RITZMANN†

GEOCHEMICAL PROSPECTING

U. S. No. 2,755,388. P. B. Weisz. Iss. 7/17/56. App. 12/12/51. Assign. Socony Mobil Oil Co., Inc.

Method for Detecting Hydrocarbon Gas. A method of soil gas analysis in which the gas is mixed with argon and an electrical discharge passed through the mixture and the rate of disappearance of metastable states of argon measured by optical absorption after the discharge is cut off, rapid quenching of the metastable states being due to hydrocarbons.

MAGNETIC PROSPECTING

U. S. No. 2,749,506. J. F. Emerson. Iss. 6/5/56. App. 8/21/50. Assign. Bendix Aviation Corp.

Magnetometer. A non-oriented magnetic detector having flux-gate pick-up elements inclined to one another, and with their secondaries connected in series to indicate field intensity or adjust a servo system to indicate direction.

U. S. No. 2,752,564. C. M. Ryerson. Iss. 6/26/56. App. 1/14/47, 10/17/55 and 12/13/55. Assign. U.S.A.

Apparatus for Detecting a Magnetic Field. A magnetic detector having a pair of parallel flux-gate elements connected to a differential peak amplifier whose output is fed to a neutralizing coil around the elements and the neutralizing current indicated.

U. S. No. 2,755,434. E. W. Yetter. Iss. 7/17/56. App. 8/16/50. Assign. Leeds and Northrup Co.

Magnetic Measuring System. A magnetic detector having a pair of saturable cores energized to saturation in opposite directions by a high-frequency a-c and with both cores surrounded by a coil carrying d-c to neutralize the ambient field and also carrying a low frequency a-c which modulates the primary current, the modulation being detected by a filter and discriminator and used to control a servo motor which adjusts the neutralizing d-c whose value is observed.

U. S. No. 2,756,383. W. E. Nold and A. C. Westhom, Jr. Iss. 7/24/56. App. 1/26/53. Assign. Nuclear Magnetics Corp.

Magnetometer Probe. A nuclear magnetic resonance test probe having a sample chamber wound with a high frequency coil and contained in a plastic case to which a coaxial cable may be attached, the case being at the center of a Helmholtz coil which produces a low frequency modulating field.

U. S. No. 2,757,335. J. Bellugue. Iss. 7/31/56. App. 3/7/51 and 3/4/52. Assign. Compagnie Generale de Telegraphie Sans Fil.

Devices for Detecting and Measuring Magnetic Fields. A magnetic detector having a motor-driven rotor with a short-circuited turn and magnetically coupled to a fixed coil whose induced emf is measured.

U. S. No. 2,760,154. F. Haalck. Iss. 8/21/56. App. 2/4/52 and 1/28/53. Assign. Askania Werke, A. G.

Magnetometer, Mainly for Geomagnetic Determinations. A torsion magnetometer whose suspension fiber is made of two materials of dissimilar temperature coefficient of elasticity so as to provide compensation for the effect of temperature on the magnetic moment of the magnet.

† Gulf Oil Corporation, Patent Department.

U. S. No. 2,760,182. A. W. Rechten and B. M. Bellman. Iss. 8/21/56. App. 2/20/51 and 2/18/52. Assign. British Telecommunications Research Ltd.

Apparatus for Detecting the Movement of Objects of Magnetic Material. A traffic detector having a U-shaped premagnetized core wound with a coil connected to a meter and having elongated pole pieces perpendicular to the plane of the core and parallel to the road surface.

U. S. No. 2,761,123. O. H. Schmitt. Iss. 8/28/56. App. 4/21/44. Assign. U.S.A.

Orientation System. An orientation control system for an airborne magnetometer using an orientation detector producing pulses of alternately opposite polarity which are demodulated and fed into a pulse shaper and used to drive a servo motor.

RADIOACTIVITY PROSPECTING

U. S. No. 2,755,390. C. F. Teichmann. Iss. 7/17/56. App. 8/6/52. Assign. Texaco Development Corp.

Detection of Mixed Radiation. A radioactivity detector using luminophors which are sensitive to different radiations and whose light is transmitted to the same photomultiplier tube by means of light pipes and a motor-driven shutter which exposes the photo-tube to the luminophors in succession on a time-sharing multiplex basis.

U. S. No. 2,758,217. S. A. Scherbatskoy. Iss. 8/7/56. App. 5/17/51. Assign. Perforating Guns Atlas Corp.

Automatic Scintillation Counter. A scintillation counter circuit in which the output pulses exceeding a predetermined threshhold are fed to a control tube which through a voltage divider lowers the high voltage on the dynodes of the photomultiplier tube.

U. S. No. 2,759,107. F. C. Armistead and T. M. McKee. Iss. 8/14/56. App. 6/20/52. Assign. Texaco Development Corp.

Scintillometer. A scintillometer whose luminophor is a noble gas which emits light on interaction with the radiation.

U. S. No. 2,759,118. R. J. Ruble. Iss. 8/14/56. App. 12/17/51. Assign. Texaco Development Corp.

Radiation Detectors. A Geiger-Mueller type of radiation detector having a fine wire anode with a number of perforated cathode plates and a tubular auxiliary electrode surrounding the array of plates, the potential between the auxiliary electrode and the cathodes being less than the anode-cathode potential.

SEISMIC PROSPECTING

U. S. No. 2,749,532. W. T. Harris. Iss. 6/5/56. App. 6/4/52. Assign. The Harris Transducer Corp.

Hydrophone. A pressure transducer having a hollow cylinder of magnetostrictive material including a permanent magnet and wound with a toroidal coil.

U. S. No. 2,750,575. W. E. N. Doty and D. B. West. Iss. 6/12/56. App. 4/6/53. Assign. Continental Oil Co.

Methods of and Apparatus for Seismogram Analysis. A system for analyzing reproducible seismograms in which the reproduced signal is fed into two different filters for momentary visual comparison of the filtered signal and the preferred signal permanently recorded.

U. S. No. 2,751,573. J. W. Millington. Iss. 6/19/56. App. 2/1/52. Assign. Sun Oil Co.

Apparatus for Changing the Resonant Frequency of a Seismic Detector. A suspended coil electromagnetic seismometer whose suspension spring is non-linear with loading so that the period can be changed by passing d-c through the coil.

U. S. No. 2,752,092. F. J. McDonal. Iss. 6/26/56. App. 10/22/51. Assign. Socony Mobil Oil Co., Inc.

Wave Analysis. A harmonic analysis system in which part of a seismogram is reproduced and sine and cosine signals generated in synchronism with the reproduction, the seismic signal and the sine and cosine signals being multiplied and integrated over the scanned interval with automatic switching at the beginning and end of the interval.

U. S. No. 2,752,466. C. R. Bonnell. Iss. 6/26/56. App. 8/11/54. Assign. Minneapolis-Honeywell Regulator Co.

Accelerometer. A variable-resistance vibrometer for high accelerations having a resistance coil mounted on a rod with ball bearings and longitudinally centered with springs which also act as leads to the coil and a contactor fixed to the case which slides on the coil.

U. S. No. 2,753,469. L. D. Statham and S. Epstein. Iss. 7/3/56. App. 12/18/50 and 6/1/54. Assign. Statham Laboratories, Inc.

Accelerometers. A motion detector having an insulation-lined chamber with elastic walls and filled with a conducting liquid, acceleration-induced motion of the liquid being detected using a transverse magnetic field and electrodes located transverse to both the field and the motion.

U. S. No. 2,753,535. J. W. Miller and G. B. Loper. Iss. 7/3/56. App. 11/7/52. Assign. Socony Mobil Oil Co., Inc.

Seismic Cable Connector. A polarized plug for connecting a geophone to the cable, the cable having cylindrical contact elements of different widths and the plug having cantilevered springs of corresponding widths which snap on to the cable contacts.

U. S. No. 2,753,544. W. H. Cox and J. W. Millington. Iss. 7/3/56. App. 10/27/53. Assign. Sun Oil Co.

Seismic Detector. A suspended coil electromagnetic seismometer having two sets of springs one with an adjustable positive spring constant and the other with an adjustable negative spring constant, the springs being adjusted to obtain a long period.

U. S. No. 2,754,085. B. W. Sewell and J. M. Camp. Iss. 7/10/56. App. 2/28/52. Assign. Esso Research and Engineering Co.

Portable Shot Hole Drill. A drill made in separable units of drill base with driving means, engine, and hydraulic system with piston from which the drill is suspended, and using tension lines to ground stakes to oppose the upward forces.

U. S. No. 2,754,434. K. Frank. Iss. 7/10/56. App. 2/10/54. Assign. Micro Balancing, Inc.

Magnetic Pickup Means. A variable-area reluctance type vibrometer having an armature fastened to the case and a U-shaped permanent magnet and coil suspended on knife edges and kept in position by the magnetic attraction between magnet and armature.

U. S. No. 2,754,435. T. Ongaro. Iss. 7/10/56. App. 9/29/52. Assign. International Research and Development Corp.

Voltage Generating Vibratory Pick-Up Devices. A moving-coil electromagnetic vibrometer whose case is connected to the vibrating prod by rubber diaphragms which filter out high frequencies.

U. S. No. 2,754,489. C. O. Randall, W. P. Weathersby, and L. D. Zepernick. Iss. 7/10/56. App. 3/2/53. Assign. Vector Mfg. Co.

Geophone-Cable. A terminal arrangement for a geophone cable in which the lead is brought out to a terminal strip wound around the cable, one strip having a small lug to accommodate a small geophone clip which cannot be attached to the larger strip so that the geophone leads cannot be reversed.

U. S. No. 2,755,734. J. T. Smith. Iss. 7/24/56. App. 12/18/52. Assign. Esso Research and Engineering Co.

Shot Hole Cap Wire Catcher. A device for preventing cap wires from being blown from a shot hole and having long concentric handles which actuate upwardly and outwardly extending arms which grip the sides of the hole.

U. S. No. 2,755,878. N. J. Smith. Iss. 7/24/56. App. 9/21/54. Assign. California Research Corp.

Method of Creating Seismic Disturbances. A system for obtaining a linear explosive in a shot hole by inserting a container having a coiled length of explosive cord and expanding the coil into a helix of desired pitch.

U. S. No. 2,755,879. M. B. Widess. Iss. 7/24/56. App. 7/2/51. Assign. Stanolind Oil and Gas Co.

Planting Seismometers. A geophone planting method in which the grass roots are removed, the ground wetted to a depth of about one-half inch, the geophone planted, and the ground allowed to dry before using the plant.

U. S. No. 2,756,406. G. A. Schurman. Iss. 7/24/56. App. 2/9/53. Assign. California Research Corp.

Vibration Detector. A suspended magnet type of electromagnetic seismometer with the magnet suspended on parallel arms hinged to the case and connected by a spring at an angle to the arms to produce a long period.

U. S. No. 2,756,836. F. Rieber. Iss. 7/31/56. App. 12/17/49 and 10/22/52. Assign. Geovision Inc.

Geophysical Display Apparatus. A system for displaying seismic data in reflection shooting in which the electron beam of a c-r tube successively samples the geophone signals at a high rate and the c-r beam traces a locus of possible reflecting surfaces so that points of traces which fit signals from all geophones are reinforced and become brighter.

U. S. No. 2,757,355. E. T. Howes and W. F. Hoy. Iss. 7/31/56. App. 7/3/53. Assign. United Geophysical Corp.

Seismic Prospecting Apparatus. A cable assembly for well shooting having a series of piezoelectric hydrophones with a sealed cable connector at the bottom of each hydrophone.

U. S. No. 2,757,356. P. E. Haggerty. Iss. 7/31/56. App. 1/8/54. Assign. Texas Instruments Inc.

Method and Apparatus for Canceling Reverberations in Water Layers. A geophone system for use in water-covered areas using two streamers whose respective detectors are maintained at different depths and their outputs combined to cancel reverberations.

U. S. No. 2,757,357. R. A. Peterson. Iss. 7/31/56. App. 8/12/53. Assign. United Geophysical Corp.

Seismic Wave Filtering System. A seismograph recording and analyzing system in which each geophone signal is recorded on magnetic tape and played back with two heads having a time displacement, the time-displaced signals being fed through two filters of different frequency response characteristic and combined and re-recorded.

U. S. No. 2,757,750. J. E. Hawkins and W. E. Pugh. Iss. 8/7/56. App. 10/8/48. Assign. Seismograph Service Corp.

Apparatus for Generating Seismic Waves. A seismic shooting system in which explosive charges are arranged in an array of shot holes and form a pattern of conical configuration or in which the charges are above the surface of the earth in a conical configuration.

U. S. No. 2,758,663. B. L. Snavely. Iss. 8/14/56. App. 3/21/55. Assign. U.S.A.

Sound Velocity Measuring System. A system for measuring the velocity of sound in water having

two electro-acoustic transducers facing each other and driven by the same a-c source of known frequency so as to set up a standing wave system and a pair of probe transducers placed at nodal points whose separation is measured.

U. S. No. 2,759,167. R. J. Clements. Iss. 8/14/56. App. 12/2/53. Assign. The Texas Co.

Seismic Detector. A seismometer having a permanent magnet with an elongated pole piece and an inertia inductor member suspended in its air gap by cantilever springs, the pole piece being wound with a coil whose emf is recorded.

U. S. No. 2,759,551. C. H. Carlisle and J. A. Smith. Iss. 8/21/56. App. 3/18/52. Assign. Esso Research and Engineering Co.

System for Seismic Exploration. A seismic prospecting system using an areal array of shot holes with charges of equal depth which are simultaneously detonated and using at each recording station an areal array of geophones whose signals are added.

U. S. No. 2,759,552. J. R. Ording. Iss. 8/21/56. App. 10/1/51. Assign. Esso Research and Engineering Co.

Seismic Exploration Apparatus. A pressure-sensitive magnetostrictive geophone made of a tube of magnetostrictive material with a diametral permanently-magnetized plate which is wound with a coil, the geophone having a resonant frequency exceeding 4000 cps and the coil connected to a band pass amplifier transmitting 20 to 150 cps.

U. S. No. 2,760,591. J. E. White and J. A. Lee. Iss. 8/28/56. App. 5/8/52. Assign. Socony Mobil Oil Co., Inc.

System for Generating Horizontally Polarized Shear Waves. A device for generating shear waves by means of a gun barrel fed with compressed gas which accelerates a cylindrical mass and the mass abruptly brought to rest against a buffer.

WELL LOGGING

U. S. No. 2,749,444. J. L. Shea. Iss. 6/5/56. App. 4/20/53. Assign. The Texas Co.

Method of Locating a Zone of Lost Circulation. A method of locating the bottom and top of lost circulation by pumping into the hole a column of radioactive mud longer than the lost circulation interval and following the bottom interface until it ceases to fall and following the top interface until it ceases to fall.

U. S. No. 2,749,446. G. Herzog. Iss. 6/5/56. App. 7/23/51. Assign. The Texas Co.

Prospecting. A gamma-ray logging system using a scintillating material whose photon production is a function of the energy of the impinging gamma rays and a photomultiplier whose signal amplitude is recorded.

U. S. No. 2,749,503. H.-G. Doll. Iss. 6/5/56. App. 11/28/51. Assign. Schlumberger Well Surveying Corp.

Electrical Logging in Non-Conductive Drilling Liquids. A method of permeability logging in oil-base mud using an electrode pressed tightly against the mud cake to squeeze the oil from the mud cake and measuring the capacity between the electrode and formation behind the zone invaded by oil filtrate.

U. S. No. 2,749,748. R. L. Slobod and S. H. Davis. Iss. 6/12/56. App. 7/16/51. Assign. The Atlantic Refining Co.

Apparatus for Continuously Logging Drill Cuttings. A device for continuously measuring the hydrocarbon content of drill cuttings in which part of the mud stream is diverted, cuttings separated

and washed and passed into the bottom of a partially water-filled closed chamber where the cuttings are comminuted and the gas in the upper portion of the chamber drawn off and analyzed.

U. S. No. 2,750,557. J. M. Bricaud. Iss. 6/12/56. App. 6/4/54. Assign. Schlumberger Well Surveying Corp.

Electrical Logging of Subterranean Formations. An electrode for very short interval electric logging having a cushion of insulating material with an exposed elliptical central electrode whose axis is parallel to the axis of the borehole and having surrounding electrodes made up of a series of small electrodes lying on ellipses confocal with the central electrode.

U. S. No. 2,750,796. W. Knoll and C. H. Biedendieck. Iss. 6/19/56. App. 6/9/50 and 5/31/51. Assign. H. Maihak Aktiengesellshaft.

Apparatus for Measuring Variable Conditions in Bore-Holes. A surface-recording well thermometer having a wire which is tensioned by a bimetallic strip, the wire being made to vibrate by an electromagnet supplied with current from the surface and the frequency measured; the apparatus also being used to determine bottom-hole pressure by measuring the temperature of a liquid which is heated until its vapor pressure equals the well pressure.

U. S. No. 2,752,504. A. S. McKay. Iss. 6/26/56. App. 2/15/52. Assign. The Texas Co.

Neutron Gamma-Ray Well Logging. A chlorine logging system in which the formations are bombarded with neutrons and gamma-rays are detected at a point vertically spaced four to six inches from the neutron source, the gamma-rays from chlorine being determined by converting the gamma rays to electrons and recording those having energy in excess of 8 mev.

U. S. No. 2,752,562. L. De Witte. Iss. 6/26/56. App. 2/2/55. Assign. Continental Oil Co.

Detection of Water in Crude Oil Flow. A method of logging a well for water entry by lowering a sonde through which the well flow passes, adding an emulsifying agent to the flow, mixing the flow constituents and measuring the dielectric constant of the emulsion flowing through the sonde.

U. S. No. 2,754,475. R. G. Norelius. Iss. 7/10/56. App. 1/28/49. Assign. Lane-Wells Co.

Borehole Diameter and Lateral Depth of Fluid Invasion Indicator. An electric logging system in which the distance between the current electrode and a pair of potential electrodes is varied by automatic switching in the sonde with synchronous recording at the surface so that a series of curves are obtained showing variation of resistivity against depth of electrical penetration.

U. S. No. 2,755,067. S. H. Williston. Iss. 7/17/56. App. 1/2/51. Assign. Sperry-Sun Well Surveying Co.

Method and Apparatus for Insulating a Drill Stem in Continuous Exploration of a Bore Hole. A method of insulating drill stem by spraying it with insulating coating as it is lowered into the well.

U. S. No. 2,755,389. S. B. Jones and T. D. Mueller. Iss. 7/17/56. App. 2/1/52. Assign. California Research Corp.

Thermal Neutron and Gamma Radiation Well Logging. A radio-activity logging method in which the formations are exposed to fast neutrons and the detector shielded from the neutron source, the detector being a crystal phosphor sensitive to both gamma rays and thermal neutrons connected to a photo-multiplier whose output pulses are fed to a differential pulse-amplitude discriminator with vibrating-reed electrometers to record the thermal-neutron pulses and the gamma-ray pulses of selected energies.

U. S. No. 2,755,430. J. G. Jackson. Iss. 7/17/56. App. 5/24/54. Assign. Eastman Oil Well Survey Co.

Apparatus for and Method of Logging Earth Bores. A method of electric logging a dry borehole us-

ing a ground connection at the surface and one electrode in the borehole which makes connection to the formation by conduction through an ionizable gas which is ionized by a source of radiation at the electrode.

U. S. No. 2,755,431. S. A. Scherbatskoy. Iss. 7/17/56. App. 7/11/50 and 6/27/52.

Logging While Drilling. A system of electric logging while drilling having a logging sub with electrodes at the bottom of the drill stem which measures the potential with a scaling circuit and controls the firing of explosive cartridges whose sound is detected and recorded at the surface.

U. S. No. 2,755,432. J. J. Arps and S. A. Scherbatskoy. Iss. 7/17/56. App. 6/27/52.

Logging While Drilling. A system of electric logging while drilling having a logging sub with electrodes at the bottom of the drill stem which measures the potential and applies it to neon tubes in voltage-divider circuits so that each tube will fire at a different potential, the successive tube pulses actuating a stepping switch which fires an explosive charge whose sound is detected at the surface and the impulse used to actuate a stepping relay and indicator.

U. S. No. 2,756,511. E. T. Young. Iss. 7/31/56. App. 12/7/51. Assign. Sun Oil Co.

Well Surveying Instrument. A multi-shot photographically-recording well surveying instrument which is dropped to a non-magnetic section of drill stem prior to pulling out of the hole, the record strip being automatically advanced upon rotating the drill stem and a record made upon stopping rotation at the desired depth.

U. S. No. 2,757,358. J. O. Ely. Iss. 7/31/56. App. 8/29/52 and 4/3/53. Assign. Socony Mobil Oil Co., Inc.

Mechanically Coupled Acoustic Well Logging System. An acoustic logging apparatus in which the mechanical coupling between the source transducer and receiving transducer has a series of masses which act as filters to attenuate transmission of the operating frequency along the coupling.

U. S. No. 2,759,143. J. J. Arps. Iss. 8/14/56. App. 7/14/54.

Earth Borehole Investigation-Signalling System. A system for logging while drilling in which time-spaced pressure pulses are produced in the drilling fluid by a three-way valve at the bottom of the drill stem, positive pressure pulses indicating one measured parameter and negative pulses indicating a second measured parameter.

U. S. No. 2,760,078. A. H. Youmans. Iss. 8/21/56. App. 5/27/52. Assign. Well Surveys, Inc.

Conduction Counter for Radioactivity Well Logging. A radioactivity detector having electrodes in an insulating solid which becomes electrically conductive when bombarded by alpha particles and surrounded by a neutron-reactive material which gives off alpha particles.

U. S. No. 2,760,079. J. J. Arps. Iss. 8/21/56. App. 11/12/48 and 6/25/51.

Well or Bore Hole Logging. A method of permeability and porosity logging in which a short-lived neutron-emitting radioactive material is added to the drilling fluid and forced into the formations and then two radioactivity logs run spaced by a time interval of several half-lives of the injected material.

U. S. No. 2,760,417. C. Laval, Jr. Iss. 8/28/56. App. 1/21/53.

Submersible Photographic Apparatus. A well camera arranged so that electric power supplied from the surface advances the film and charges a condenser which discharges through a lamp when the power is interrupted, the lamp being located some distance below the camera to reduce the reflection of light from particles suspended in the well fluid.

U. S. No. 2,761,103. H.-G. Doll. Iss. 8/28/56. App. 8/5/52. Assign. Schlumberger Well Surveying Corp.

Induction Well Logging Apparatus. An induction logging sonde using coils whose axis is parallel to that of the borehole and having insulating radial barriers which interrupt eddy currents in the borehole fluid.

See also Patents 2,755,390; 2,758,217; 2,759,107; 2,759,118; listed under Radioactivity Prospecting.

MISCELLANEOUS

U. S. No. 2,749,220. R. W. Rochon. Iss. 6/5/56. App. 9/21/53. Assign. Monarch Logging Co., Inc.

Method for Measuring Gas in Cores. A method of determining the amount of hydrocarbon gas in a core sample by immersing the core in mercury, reducing the pressure to extract gas from the core, introducing air to form a gas-air mixture, and determining the concentration of hydrocarbons with a hot-filament gas analyzer.

U. S. No. 2,749,436. R. H. Rines and I. S. Blonder. Iss. 6/5/56. App. 7/17/48, 1/23/51 and 1/30/51.

Sonobuoy. A sonobuoy having a reflecting radar antenna whose circuit is affected by acoustic waves received in the water so that radio waves reflected from the antenna are modulated in accordance with the acoustic waves received, or having a transmitter whose radiating antenna is switched in accordance with received acoustic waves.

U. S. No. 2,753,717. V. F. Obrcian. Iss. 7/10/56. App. 2/4/54.

Soil Density Gauge and Sampler. A soil sampler having a tripod which guides a cutter cylinder to cut a sample of fixed size.

U. S. No. 2,754,512. H. Davis and S. Rosenberg. Iss. 7/10/56. App. 6/26/51.

FM Long Range Navigation System. A loran system using a transmitter which radiates two f-m carriers and a marker signal, and two spaced slave stations which reradiate the respective carriers, the mobile station using an a-m receiver and determining the time between the marker signal and a null in the received modulating signal.

U. S. No. 2,754,719. P. De Chambrier. Iss. 7/17/56. App. 8/16/54. Assign. Schlumberger Well Surveying Corp.

Methods and Apparatus for Determining Displacement Between Curves. A curve correlator having two optical systems which are simultaneously adjusted to bring two transversely-separated curves into superposition and also simultaneously adjusted to bring longitudinally-separated portions into correlation with the latter adjustment indicated.

U. S. No. 2,755,660. K. Kammermeyer and D. W. Brubaker. Iss. 7/24/56. App. 6/12/53. Assign. State University of Iowa.

Permeability Tester. A device for testing the permeability of sheet material by applying a fluid pressure on one side of the material and measuring the amount of fluid which passes through by movement of a slug of mercury in a capillary tube.

U. S. No. 2,756,585. R. L. Irby. Iss. 7/31/56. App. 7/23/53. Assign. Rotary Engineering Co.

Detection of Gas Bearing Formations. A method of detecting gas in formation cuttings in the mud returns by submerging the cuttings in a transparent liquid in a closed container with a transparent lid, slowly evacuating the container and observing the evolution of bubbles with a microscope.

U. S. No. 2,757,533. B. F. Wiley. Iss. 8/7/56. App. 1/2/51. Assign. Phillips Petroleum Co.

Gas Leak Detector for Well Casing. A device for detecting casing leaks in a shut-in gas well having a weighted packer which seals against the casing and has an opening with a whistle or siren whose sound is detected at the surface by a microphone.

U. S. No. 2,758,203. W. T. Harris. Iss. 8/7/56. App. 6/28/52. Assign. The Harris Transducer Corp.

Sonobuoy. A radio-sonobuoy having a transducer assembly which rests on the water bottom and is connected by a cable to a floating radio antenna, the cylindrical transducer case carrying on its outer surface a cylindrical magnetostrictive hydrophone.

U. S. No. 2,760,180. G. Sipkin. Iss. 8/21/56. App. 10/6/49.

Long Range Explosive Sonobuoy. A sonobuoy having a hydrophone whose signal is amplified and triggers the release of a depth domb which explodes at the depth of the oceanic sound channel.

SELECTED LIST OF U. S. PATENTS ISSUED DURING JUNE, JULY, AND AUGUST OF 1956

Patent No.	*Subject**	*Patent No.*	*Subject**	*Patent No.*	*Subject**
2,748,485	68	2,750,511	196	2,751,313	224
2,748,487	68	2,750,512	416	2,751,438	224
2,748,602	288	2,750,513	308	2,751,439	224
2,748,700	136	2,750,514	308	2,751,440	224
2,749,035	16, 68	2,750,515	308	2,751,441	484
2,749,036	68	2,750,516	308	2,751,475	484
2,749,037	68	2,750,517	308	2,751,476	484
2,749,038	68	2,750,545	68	2,751,505	308
2,749,204	324	2,750,557[a]	116	2,751,539	16
2,749,205	324	2,750,561	228	2,751,540	16
2,749,220[a]	88	2,750,562	140	2,751,541	16
2,749,221	168	2,750,569	40	2,751,542	16
2,749,391	224	2,750,574	108	2,751,543	16
2,749,392	484	2,750,575[a]	360	2,751,573[a]	376
2,749,393	484	2,750,583	308	2,751,576	288, 484
2,749,436[a]	444, 312	2,750,584	68	2,751,577	12
2,749,444[a]	304	2,750,658	224	2,751,588	316
2,749,446[a]	304	2,750,794	332	Re.24,170	224
2,749,503[a]	116	2,750,796[a]	452, 288	2,751,689	108
2,749,504	228	2,750,798	16	2,751,777	168
2,749,506[a]	232, 216	2,750,800	148	2,751,783	140, 12
2,749,531	436	2,750,831	136	2,751,785	16
2,749,532[a]	376, 436, 484	2,750,834	196, 416	2,751,786	16
2,749,746	428	2,750,884	136	2,751,811	416
2,749,748[a]	252	2,750,885	48	2,752,091	68
2,749,754	288	2,750,886	136	2,752,092[a]	12, 360
2,749,840	48	2,751,011	392	2,752,093	68
2,749,841	48	2,751,020	392	2,752,428	484
2,750,109	68	2,751,148	68	2,752,466[a]	4
2,750,110	68	2,751,149	68	2,752,502	236
2,750,247	316	2,751,169	16	2,752,504[a]	304
2,750,248	68	2,751,274	224	2,752,505	308
2,750,436	40	2,751,275	324	2,752,506	308
2,750,449	224	2,751,281	168	2,752,508	308

* A key to the subject classification system will be found in GEOPHYSICS, v. 12, pp. 256–264 (April, 1947).

[a] Abstracted on preceding pages of this issue.

Patent No.	Subject*
2,752,512	12
2,752,558	484
2,752,562[a]	116, 508
2,752,564[a]	232
2,752,584	12
2,752,684	16
2,752,778	496
2,752,787	288
2,752,789	16
2,752,790	16
2,752,791	16
2,752,792	16
2,752,793	16
2,752,848	136
2,752,849	136
2,752,879	16
2,752,949	288
2,753,112	68
2,753,173	16
2,753,238	332
2,753,247	168
2,753,462	308
2,753,463	308
2,753,466[a]	4
2,753,524	12
2,753,535[a]	40
2,753,542	200
2,753,543	484
2,753,544[a]	376
2,753,551	316, 312
2,753,554	316
2,753,555	316, 312
2,753,556	316
2,753,713	460
2,753,714	460
2,753,717[a]	404
2,753,718	16
2,753,753	420
2,753,885	200
2,753,935	48
2,754,053	68
2,754,055	68
2,754,059	68
2,754,069	324
2,754,085[a]	360
2,754,170	324
2,754,434[a]	376
2,754,435[a]	492
2,754,457	200
2,754,475[a]	116
2,754,489[a]	40
2,754,492	316, 108
2,754,501	16
2,754,506	316
2,754,509	316
2,754,510	316
2,754,512[a]	312
Re.24,182	224
2,754,569	224
2,754,596	200
2,754,676	412
2,754,682	428
2,754,683	428
2,754,687	68
2,754,719[a]	68, 116
2,754,755	136
2,754,757	136
2,754,789	16
2,754,925	12
2,755,020	68
2,755,021	68
2,755,067[a]	116
2,755,160	224
2,755,163	324
2,755,253	308
2,755,343	484
2,755,388[a]	168, 396
2,755,389[a]	304
2,755,390[a]	304
2,755,391	308
2,755,427	16
2,755,430[a]	116
2,755,431[a]	208, 116, 516
2,755,432[a]	208, 116, 516
2,755,434[a]	232
2,755,439	48
2,755,441	308
2,755,443	160
2,755,455	108
2,755,456	16
2,755,462	316
2,755,464	316
2,755,562	216
2,755,660[a]	276
2,755,662	12
2,755,664	148
2,755,667	288
2,755,668	148, 288
2,755,734[a]	360
2,755,735	136
2,755,736	136
2,755,767	484
2,755,796	484
2,755,878[a]	360
2,755,879[a]	376
2,755,994	68
2,756,009	16
2,756,010	16
2,756,011	16
2,756,057	224
2,756,276	224
2,756,278	224
2,756,280	224
2,756,281	484
2,756,295	188
2,756,339	236
2,756,340	236
2,756,341	236
2,756,342	196
2,756,345	308
2,756,346	308
2,756,347	308
2,756,348	308
2,756,353	484
2,756,383[a]	232
2,756,406[a]	376
2,756,407	16
2,756,417	316
Re.24,191	484
2,756,506	520
2,756,511[a]	520
2,756,585[a]	252
2,756,588	428
2,756,590	428
2,756,592	428
2,756,594	148
2,756,595	460
2,756,598	16
2,756,645	136
2,756,677	48
2,756,836[a]	360
2,756,928	68
2,756,929	68
2,756,930	68
2,757,099	224
2,757,242	224
2,757,290	168
2,757,291	308
2,757,292	308
2,757,335[a]	232

Patent No.	Subject*
2,757,354	108
2,757,355[a]	376, 484
2,757,356[a]	360
2,757,357[a]	360
2,757,358[a]	8
2,757,456	224
2,757,533[a]	144
2,757,538	148
2,757,566	136
2,757,568	416
2,757,750[a]	360, 136
2,757,863	68
2,757,887	16
2,758,203[a]	444, 312
2,758,214	236
2,758,217[a]	308
2,758,276	228
2,758,288	484
2,758,294	460
2,758,298	316
2,758,299	316
2,758,470	188
2,758,473	148
2,758,474	200
2,758,476	288
2,758,663[a]	12, 436, 108
2,758,712	140
2,758,786	68
2,758,787	68
2,758,788	68
2,758,905	224
2,758,906	324
2,759,105	236
2,759,107[a]	308
2,759,118[a]	308
2,759,143[a]	208, 116, 516
2,759,149	188
2,759,157	4
2,759,167[a]	376
2,759,168	108
2,759,267	68
2,759,272	192
2,759,354	168
2,759,355	496
2,759,417	48
2,759,418	136
2,759,551[a]	360, 136
2,759,552[a]	360, 376
2,759,677	224
2,759,783	108, 436
2,759,784	68
2,760,037–040	428
2,760,064	308
2,760,078[a]	304
2,760,079[a]	304
2,760,153	228
2,760,154[a]	232
2,760,168	484
2,760,180[a]	444, 436
2,760,181	484
2,760,182[a]	232
2,760,187	316
2,760,189	316
2,760,190	316
2,760,369	12
2,760,372	200
2,760,373	200, 460
2,760,376	16
2,760,404	68
2,760,417[a]	280
2,760,434	48
2,760,435	48
2,760,509	484
2,760,580	392
2,760,591[a]	360
2,760,758	80
2,760,840	324
2,761,016	224
2,761,017	224
2,761,043	288, 484
2,761,067	420
2,761,068	324
2,761,070	308
2,761,071	308
2,761,073	308
2,761,077	484
2,761,100	16
2,761,103[a]	128
2,761,117	484
2,761,118	484
2,761,123[a]	232
2,761,131	316
2,761,132	316
2,761,133	312

REVIEWS

REVIEWS COMMITTEE

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CONTENTS

Diffraction of a Longitudinal Pulse from a Wedge in a Solid, W. W. Grannemann, by *Franklyn K. Levin* 147
The Lamb Problem for a Medium with an Elastic Aftereffect, E. I. Shemyakin, by *Leon Knopoff* 147
Model Seismology (Part I), Yoshio Kato and Akio Takagi, by *Franklyn K. Levin* 148
Structural Geology, L. U. de Sitter, by *Robert J. Watson* 149
The Potentials About a Point Electrode and Apparent Resistivity Curves for a Two-, Three-, and Four-Layer Earth, Harold M. Mooney and W. W. Wetzel, by *Irwin Roman* 150

Diffraction of a Longitudinal Pulse from a Wedge in a Solid, W. W. Grannemann. The *Journal of the Acoustical Society of America*. Vol. 28, 1956, pp. 494–497.

From the point of view of the exploration geophysicist, too few of the papers on seismic models have treated problems of immediate interest. More than one experimenter has investigated only the relatively simple Lamb theory but this complaint cannot be made of Dr. Grannemann's work. His three dimensional models were used to study diffraction of longitudinal pulses from a 90 degree step and a 10½ degree wedge. The agreement between experimental results and theoretical predictions, the latter based partly on Dr. Grannemann's Ph.D. thesis, is gratifying.

Dr. Grannemann's models were made of tar poured over concrete, the whole being in a steel tank. To get sufficient energy, he used five in-line barium titanate transducers as a source, a single barium titanate as a detector. The input pulse was 1½ cycles of a 50 kcps sine wave. Diffracted longitudinal pulses were recorded from both the step and wedge models; although, due to an unfortunate geometry, only over a limited range along the surface. Receiver and source directivity patterns were found from hemispherical tar models; this technique is not new but the method of determining the attenuation constant—comparison of the direct and focussed reflected pulses—was ingenious. As indicated above, Dr. Grannemann confirmed his theoretical predictions within experimental error. Those of us who have measured amplitudes on seismic models know the data scatter can be both large and annoying.

In spite of the overall excellence of the paper, this reviewer has two minor complaints. First, an $[r]^{-1}$ correction was applied to the wedge but not the step model. Second, experimental results are expressed as relative amplitudes but nowhere does Dr. Grannemann state his standard amplitude. That information surely would have made the curves more meaningful.

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The Lamb Problem for a Medium with an Elastic Aftereffect, E. I. Shemyakin, *Doklady Akademiia Nauk SSSR*, Vol. 104, No. 2, Sept. 11, 1955, pp. 193–196. (In Russian)

Viscoelastic or other linear, imperfe[illegible]v elastic models are often introduced in theoretical seismology in an attempt to account for loss or [illegible]spersion in seismic wave propagation. If, in the case of

perfectly elastic media, a given boundary value problem can be solved, the solution to the corresponding problem in the case of dissipative media is far more difficult, if not impossible. One case which comes to mind, illustrating the intense mathematical difficulties involved, is the solution by Miss Newlands to Lamb's problem when the half space possesses a generalized viscoelastic property.

In the paper above, the author obtains a useful result in which he demonstrates that, if the perfectly elastic case has a known solution, the corresponding problem for the imperfectly elastic case may be obtained by a convolution of the elastic result. The convolution kernel is the solution to the one-dimensional problem of wave propagation in the dissipative medium with the initial conditions of a specified stress at one point in the medium, the medium being otherwise at rest at the starting time.

The dissipative properties of the medium are introduced by means of a "memory" function. The concept is coincidentally used in the contemporary work of Collins and Lee reported in GEOPHYSICS. Actually, both papers trace the idea of a memory or aftereffect function back to a paper by Boltzmann appearing in 1876. Shemyakin indicates a procedure by which the memory function can be determined from measurements of damping and dispersion. This procedure is similar to that given by Collins and Lee. If, however, one assigns certain dissipative properties to seismic media, the convolutions are made specific and the integration may be attempted.

The author makes no attempt to solve any specific boundary value problem or to insert any specific loss properties for seismic media. This reviewer has applied the Shemyakin convolutions to Lamb's problem for a medium possessing the "Q" characteristic of loss attributed to real seismic materials by Born, Birch, Collins and Lee, etc. This integration checks a result previously obtained by more laborious methods. The Jeffreys model of loss has been incorporated in Lamb's problem and Shemyakin's method checks Miss Newlands' result. This reviewer has now applied the procedure to three additional problems with some labor but with reasonable success. In these cases it has been demonstrated that the mathematical difficulties have not been always resolved; only the setting up of the solution to the boundary value problem has been by-passed.

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Model Seismology (Part I), Yoshio Kato and Akio Takagi, *Tôhoku University Science Reports*, V. 7, pp. 35–44, 1955.

To the growing list of academic and industrial laboratories studying seismological problems with ultrasonic models can be added the Geophysical Institute of Tôhoku University. The present paper is restricted to two simple cases: pulses propagated over the surface of a semi-infinite medium and pulses propagated over the surface of a two layer section with a step discontinuity. Two dimensional (thin plate) models were used.

Neither the problems studied nor the results reported are new. However, Kato and Takagi have introduced a new technique into model technology. Detection of the horizontal component at the surface is difficult; with detectors placed against a small vertical step in the model edge, Kato and Takagi detected this component and were able to draw hodographs for the compressional and Rayleigh waves. The S wave was not recorded as a separate arrival.

In regard to one point, the reviewer must take exception. The authors refer to their first case as the Lamb problem, apparently meaning by this Lamb's investigation of an infinite line source on a semi-infinite medium. Until the amplitude characteristics of edge excited two dimensional models have been treated theoretically, the correspondence with Lamb's work is not obvious.

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Structural Geology, L. U. de Sitter, Geological Institute of the University of Leiden, Holland. McGraw-Hill Book Company, Inc., New York, 1956, 552 pp., $11.00.

As stated on the paper jacket, this is an advanced and scholarly textbook on structural geology. It is a new addition to the McGraw-Hill series in the Geological Sciences for which Professor R. R. Shrock is consulting editor. The author writes in the English language; the book is not a translation.

Professor de Sitter states in his preface that the book is intended for the trained geologist and it presupposes on the part of the reader a familiarity with the elements of structural geology and its terminology. The aim of the book, the author states, is to establish a link between theory and practice. It is the opinion of the reviewer that Professor de Sitter has done this very well.

The following quotation indicates his philosophy of structural geology: "Structural Geology is concerned with all aspects of the earth's crustal distortion. It is a descriptive science which needs its own systematic classification of rock formation, i.e. *comparative structural geology*. Since it also aims to explain *how* the crust has been distorted, it needs a theoretical and experimental background. This is found in *theoretical and experimental structural geology*. Finally it must explain *why* the earth's crust has been deformed at all, which necessitates an analysis of the distribution and interrelations of structural features all over the earth. This is the concern of the science of *geotectonics*."

Accordingly, the book is divided into three main sections:

1. Theoretical Structural Geology—110 pages, 77 illustrations
2. Comparative Structural Geology—208 pages, 171 illustrations
3. Geotectonics—183 pages, 61 illustrations

It would take too much space in this review to list all the topics discussed. As may be inferred from the number of pages devoted to each main section, indicated above, the presentation is thorough. The inclusion of the latest topics of interest and argument in the field of structural geology makes the book satisfying.

The first section discusses the physical properties of rocks and how these properties influence elastic, plastic and rupture deformation. While not highly mathematical, the treatment is not simply descriptive and should prove interesting to the geophysicist. The author believes that only recently have laboratory experiments been made from the purely geological point of view and it has become apparent that, even in relatively short experiments, time plays a predominant role. The boundary between the elastic and the plastic fields has become ill-defined and one should study these fields carefully before developing any theories about deformation either in the earth's crust as a whole or in a special layer within it. Considering one phase of experimental studies he says—"Quite another kind of approach to the understanding of structural shapes is the imitative experiment, which in spite of a lack of theoretical background has blundered into quite surprising results. None the less, its limitations are now clearly visible and we do not believe it can bring much fundamental knowledge."

In the section of Comparative Structural Geology, which is the longest in the book, all the common types of structures are discussed in considerable detail. Many topics such as diapiric and collapse structures, gravity sliding, and the interference of structures of different phases, which find rather scant treatment in the usual structural geology text, are here given fuller discussion. In the preface to this section he points out a fact that cannot be stressed too much.—"It is obviously impossible for one geologist to see and judge with his own eyes a sufficient number of typical structures, and he is obliged to draw heavily on published reports. But in the majority of cases the published sections and maps are *interpreted* representations of the observed facts and not the facts themselves, and are therefore strongly charged with subjective views of the observer. By using these data indiscriminantly we should probably arrive at a classification of different schools of thought instead of a systematic classification of structures."

The section on Geotectonics is, to the reviewer, the most fascinating part of the book. The topics cover the whole range of geophysical and geological facts and speculation. Professor de Sitter obvi-

ously enjoys his look at the "big picture" in structural geology. Perhaps the reviewer can give something of the flavor of the author's writing by some more quotations.

While making careful distinction between fact and fancy in geophysics, he gives that science proper credit. "It is no over-statement to say that only since geophysical methods have been employed to explore basins for oil have we obtained positive knowledge of their structure."

Concerning geotectonical synthesis he writes—"This most fascinating subject in Structural Geology, the geotectonical synthesis of all structural knowledge, is at the same time in a certain sense its most unsatisfactory branch, because so many totally unknown and untested properties of the deeper crust, the mantle and the core of the earth are involved. It is the territory of the most unchecked and flamboyant fantasy, built up by piling hypothesis on theories, shored by very rare and thin reeds of geophysical facts. Even the factual geologic data are woefully inadequate for a geotectonic description of our earth's surface and too many immense regions are totally unknown or only superficially known. Nevertheless, it seems useful to marshal those facts which are known, and those which can be directly interpolated from them, into one comprehensive picture. My effort in this direction is contained in Part III; its usefulness perhaps lies principally in bringing out the flimsiness of all present geotectonic concepts, including my own."

The printing of the text and the 309 illustrations, all line drawings, are easy to read. The index, while rather short, is perhaps adequate. A reference bibliography of 489 entries is an indication of the scope of the author's reading. Of these only some 153 refer to publications in the United States and Canada. The book will therefore be of special interest to geoscientists in the Western Hemisphere because in one handy volume there are gathered together data which do not ordinarily come to us in convenient form. This is a book which should make a stimulating addition to the library of anyone active in the field of structural interpretation of geophysical and geological data.

ROBERT J. WATSON
The Carter Oil Company
Tulsa, Oklahoma

The Potentials About a Point Electrode and Apparent Resistivity Curves for a Two-, Three-, and Four-Layer Earth. Harold M. Mooney and W. W. Wetzel, The University of Minnesota Press, Minneapolis, Minnesota, 1956. 146 pp., 243 loose sheets of reference curves, $18.00 (Text only $4.50; Curves only $15.00).

The professional geophysicist who is interested in the interpretation of resistivity observations will welcome this album of curves and should find it valuable, if he does not require an accuracy beyond that of customary field data and geological requirements. The project of organizing and calculating of the tables and the preparation of the album of curves was an ambitious one made feasible by grants of funds for research, by cooperative efforts of numerous individuals, and by the availability of automatic digital computing devices. The fundamental formulas have been in print for more than 25 years but, except for a few scattered curves, no one has been willing to undertake the enormous tasks of calculation, drawing, and finding a sponsor for publication.

The text contains 22 pages of explanations, a page of 17 bibliographic references, over 2,400 tables of potential values, and two auxiliary tables. The album consists of one sheet with 20 two-layer curves, 35 sheets with about 350 three-layer curves, and over 200 sheets with more than 2,000 four-layer curves. Eleven sets of four-layer curves are missing: all but two of these have a bottom layer of high resistivity and a second or third layer of good conductivity. The two exceptions have resistivity ratios of 1:1/10:10:1/100 and 1:1/100:100:10, respectively. The omission of these curves and of the one or two curves for other sets should not prove to be a serious handicap in the matching of curves of observed data with curves of the album. All curves show the disturbing factors (the ratio of the apparent resistivity to the resistivity of the upper layer) for the Wenner or Lee partitioning configuration of measurement.

The curves may be used without an understanding of the text or of the methods of calculation. Each sheet of curves represents one set of resistivity ratios which is indicated on the sheet. Each curve is labeled with the depths of the successive boundaries, of which the deepest is always six units.

The sheet also shows the code for reference to the tables, but this code is of no interest to the interpreter. The *X* of the code on the sheet is a flag requiring reference to the individual thicknesses as coded in the text.

To use the album for interpreting Wenner or Lee curves, the apparent resistivity is plotted as ordinate and the separation is plotted as abscissa on double logarithmic paper of a five inch cycle. The observed curve is compared with the curves of the album until an acceptable match is determined. If this is possible, the resistivity of the upper layer is the apparent resistivity which corresponds to the resistivity index of the reference curve as indicated by the heavy horizontal line. The depth of the bottom of the third layer is the separation which corresponds to the depth index of the reference curve as indicated by the heavy vertical line. The other resistivities are obtainable from the interpreted resistivity and the ratios shown on the sheet. The unit of depth is one-sixth of the interpreted depth and the depths to the boundary planes are obtainable from the depths shown on the curve of match.

If no match is acceptable, interpolation may be used, if the observed curve can be assumed to lie between two of the reference curves, especially if these differ in only one parameter. Often, a match is not unique and the interpreter has the choice of listing the various interpretations with some estimate of their relative weights or of making a selection on the basis of outside information.

Because of the need for five parameters, no single arrangement of curves is natural and interpolation may require the use of curves from several sheets which may be scattered through the album. Experience will assist the interpreter in selecting reference curves likely to fit the observed curve or to lead to interpolation. A guess based on familiarity with the album, or a fitting of the portions of the curves in order, may speed the matching process, but no rules can be given for the process of selection.

In extreme cases, one of the missing curves may be needed. In such cases, the interpreter must rely on his judgment—unless he is able and willing to perform the lengthy numerical evaluation needed to determine the missing curve.

The text discusses the mathematical aspects of the problem and gives a general outline of the methods of calculation. Although the programming of the computer is important, most readers would be unable to follow such a program unless familiar with the performance of the specific machines used and the accuracy of the machine calculations must be taken for granted. Likewise the checks on internal performance may be assumed to be adequate. The inaccuracies of the results are indicated by the need of smoothing. A code of some sort would be desirable to indicate the probable reliability of each table and of each curve, but this may not be possible without unwarranted effort and investigation.

The text contains about 2,400 tables of potential values, for various combinations of thicknesses and resistivities. Each table contains 13 entries for lateral displacements, which are either 0.5 or 3 multiplied by powers of two and not over a hundred. This doubling of displacements is adapted to the Wenner or Lee system, but will prove useful for other configurations involving only the tabulated displacements or for those for which interpolation within the table is sufficiently reliable.

The tables are identified by a four-digit code. The first digit designates the combination of thicknesses, the sum always being six. Thicknesses of 1, 1, 4 are coded as 1, those of 1, 2, 3 as 2, etc. The final three digits of the code show the resistivities of the successive layers referred to the resistivity of the top layer. The resistivities 100, 10, 3, 1, 1/3, 1/10, and 1/100 are coded as 1 to 7, respectively. For example, the code 0324 indicates that the thicknesses have the ratios 3, 2, 1 and the resistivities the ratios 1:3:10:1.

The solution of the mathematical problem is in terms of Bessel functions. The formulas for the four-layer case are shown explicitly; degenerate cases of two or three layers correspond to equality of resistivities in adjacent layers. The solution involves an integration over the interval from zero to infinity and an integrand involving the product of a Bessel function and a function of the variable of integration as determined by the boundary conditions. This integral is divided into two parts, one from zero to 1.6 and the other from 1.6 to infinity. In the finite portion, the multiplier function is approximated by a quadratic polynomial over each elementary step of the integration. The re-

mainder integral is replaced by an approximation whose value from zero to infinity is known, and whose value from zero to 1.6 may be determined as for the finite integral. The values of the coefficients used in the numerical quadrature and of the remainder terms are shown in tables.

A few minor suggestions may be noted:

p. 6. A reference to U. S. Bureau of Mines Technical Paper 502 (1931) should have been included as basic. The work of Hummel should also have been mentioned.

p. 7. The statement that Table C can be used for "any arrangements of electrodes" may be misleading, as graphical or numerical interpolation may be required.

p. 8. The italicized conclusion is one of the unresolved problems of the profession. No calculated curve has been shown to violate this conclusion but in practice such apparent violations have served for valid interpretations verified by drilling.

p. 12. In Figure 6, the designation of the resistivity ratios is omitted, although it is clearly indicated in the text.

p. 13. The fraction should be solved algebraically for the ratio of resistivity in terms of R_1. The reader must do this to determine the value of R_2.

p. 21. In the remainder term, a reference to the table on page 18 would clarify the choice of 1.6.

p. 21. It would clarify the approximation if some limit of error were stated. The agreement of two integrands at infinity does not prove their agreement over the entire range of integration.

p. 23. In equation 29, the second term must be multiplied by 2.

The plates leave something to be desired. Some of the printing is so poor as to be almost illegible. The curves have erratic humps, sharp changes in slope, and inverted curvatures. Some curves approach their asymptotes at sharp angles and appear to cross them. A test curve calculated from the tables did not track the curve shown. However, departures from ideal curves seem to fall within the permissible tolerance of field observations. As smoothing was used, some discrepancies may be anticipated. In some interpretations the curve errors combined with observational errors may confuse the interpretation, especially in ambiguous matchings.

If used with care and caution, the album of curves should aid the interpreter in finding a plausible explanation of observed data. Until more precise calculations are available, the present curves will prove useful. Only experience can determine whether the inherent accuracy is sufficient.

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LETTER TO THE EDITOR

In his article "Seismic Waves from a Transducer at the Surface of Stratified Ground," GEOPHYSICS, October 1956, p. 939, F. F. Evison makes the following statement concerning a paper written by Eugene Usdin and myself in GEOPHYSICS, v. 18, No. 4, October 1953, p. 844 (Dispersive Properties of Stratified Elastic and Liquid Media: A Ray Theory); "The group velocity curve shown by Tolstoy and Usdin for the second mode appears to be in error."

This statement of Evison's is, unfortunately, correct. It refers to the M_{21} group velocity curve of Figure 10. The first minimum on this curve should have been considerably deeper, corresponding to values of U/β, of the order of 0.8, as can be easily verified by graphical differentiation. The rest of the curve, however, is all right.

IVAN TOLSTOY
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MEMORIAL

CHARLES HARRY CARLISLE

Charles Harry Carlisle died of a heart attack on August 12, 1956. "Chili," as he was known by all of his friends, died very peacefully in his sleep while awaiting hospital tests to determine the seriousness of his illness. His untimely death at the age of 47 brought to a close an outstanding career in geophysics.

He was born in Summerville, Texas, on February 17, 1909, but lived most of his life in Houston where he graduated from old Central High School in 1926 and from The Rice Institute in 1932. He also attended Texas A & M during the school year 1927–28.

Chili started to work on a seismograph crew for Humble Oil & Refining Company on January 14, 1933. After less than eight months with Humble, he went to Roumania where he served for a little over a year as shooter and operator on a seismograph crew. He was back in the United States about a month when on January 6, 1935, he went to Mexico for similar work. Before returning from Mexico, his high school sweetheart, Yvonne Reynolds, met him in Tampico and they were married on December 14, 1935.

After his return to the United States in May, 1936, Carlisle's work with Humble's field seismograph crews took him to many parts of West and East Texas. At the beginning of World War II, he was transferred to Houstor to assist in the development and maintenance of seismograph equipment and was given the responsibility of servicing all Humble's seismograph crews. As the need developed during the war years and post-war years other men were assigned to assist him in this work and the Geophysical Service Group was formed with Chili as its supervisor. He maintained this position until July, 1955, when he became Assistant Chief of Geophysics Research—the position he held at the time of his death. During the war and post-war years, Chili's unbounded enthusiasm and optimism for geophysical work led to many developments which were very beneficial to his company and to the geophysical industry.

Chili's appealing manner and contagious sense of humor made him a favorite companion of his many friends. He was very devoted to his lovely wife, Yvonne; his son, Charles H. Carlisle, Jr., who is a student at Texas University, and to his daughter, Barbara, who attends Lamar High School in Houston.

He was a member of the Institute of Radio Engineers, the national Society of Exploration Geophysicists, and the Houston section of S.E.G. He will be keenly missed and long remembered by all of his friends and associates.

J. ANGELO SMITH

November 9, 1956

MEMORIAL

CARL A. HEILAND

Dr. Carl August Heiland died February 23, 1956 in Denver. His unexpected death following an embolism associated with a badly fractured ankle came as a shock to his associates and friends.

Dr. Heiland was born July 16, 1899, in Hamburg, Germany. He was educated at Wilhelm Gymnasium and the universities of Heidelberg and Hamburg, receiving the degree of Doctor rerum Naturalium in 1923.

Following two years in the geodetic and geophysical instrument department of Askania Werke in Berlin, he came to Houston as Askania's American representative in 1925.

At the instigation of the late Max Ball, Dr. F. M. Van Tuyl, and the late President M. F. Coolbaugh, Dr. Heiland joined the faculty of the Colorado School of Mines late in 1926. The following January he began the first formal course in geophysical prospecting to be given in the U. S. It considered the intricacies of the torsion balance and was followed by courses in magnetic, electric and seismic exploration. He remained as head of the Mines geophysics department until 1948, when he retired from academic life.

After an association of several years with Plains Exploration Company, Dr. Heiland became co-founder and president of Heiland Research Corporation early in 1934. He remained as president of the corporation and its successor, the Heiland Division of Minneapolis-Honeywell, until his death.

Dr. Heiland contributed many technical papers throughout his professional life and authored "Geophysical Exploration" in 1940. Besides SEG, his society affiliations included Geological Society of America, American Association of Petroleum Geologists, American Institute of Mining, Metallurgical and Petroleum Engineers, Society of Economic Geologists, American Geophysical Union and the Seismological Society of America.

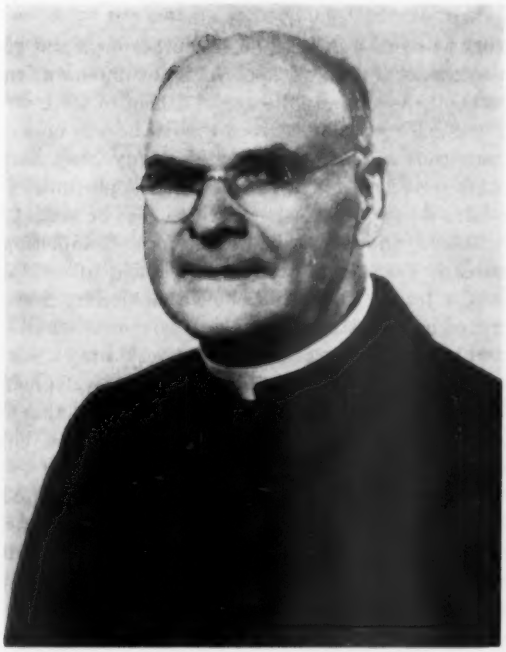
Surviving are his widow, Peggy, a daughter, Ann, and a young son, John Thomas.

As a pioneer of geophysical prospecting and one of its earliest teachers, his loss is felt by professional colleagues and former students throughout the world.

JOHN C. HOLLISTER

March 2, 1956

MEMORIAL



JAMES BERNARD MACELWANE, S.J.

That the late Reverend James Bernard Macelwane was well-known in the field of seismology throughout the world is evident from the literature in this field. His scholarly contributions to seismology were numerous and often referred to in the publications of seismologists. It comes as a surprise to many when they learn of his interest in the more practical phases of geophysics, namely, exploration geophysics. Few are aware that he worked with the pioneers in this country in exploration for oil.

As early as 1924 he was retained by the Reiber Exploration Company as a consultant in seismic exploration. He served in the same capacity for the old General Geophysical Company owned by Major Martin Connolly. Nor were his services limited to these two companies.

Just as Father Macelwane's eminence in pure seismology bears an unexpected relation to his interest in the applied field, so his early life and more mature years reveal an unpredictable chain of events. Born on September 28, 1883, he was brought up on a farm with his four brothers and three sisters on the northern shore of Sandusky Bay off Lake Erie. He was the oldest of the children to

grow up on the farm. Hence, he early learned to be useful in doing the chores. As he grew older he took on the heavier work in the fields, vineyard, and fishing with nets in the bay.

When the work at home was light, he, like other boys and girls in his neighborhood, attended the local public school. As was common at the time, he gave up elementary school education at the age of fifteen to work with his father on the farm and in the fishing business. Even though he was now out of school, he occupied his leisure time in reading and further study. Such liking for study led his parents to think seriously of giving him further opportunities in school. After working on the farm for two years, they decided that he should enter St. John's High School in Toledo, Ohio. This he did in 1901. Completing three years of high school courses in two years, he was determined to seek admission to the Society of Jesus (the Jesuit Order) to become a missionary priest.

He was admitted in August, 1903, to the Jesuit novitiate in Cleveland, Ohio. Except for several hours of study of Latin and Greek a week, his principal attention for the next two years was given to his religious development as a novice in the Jesuit Order. After these two years, he was satisfied that the religious life of a Jesuit was suited to his ability and liking. He took the religious vows that made him a member of the Jesuit Order.

He next entered upon a course of studies normally required of Jesuits preparing for the priesthood. Interspersed with several years of teaching, he studied at Saint Louis University ancient and modern languages, literature and history, natural sciences and mathematics, philosophy, psychology, and theology. He was ordained to the Catholic priesthood in 1918.

Although as a Jesuit novice he favored the idea of being a missionary, with the passing years the challenge of school teaching came upon him. With a liking for the classical languages, he looked ahead to a career in the classroom teaching Latin and Greek. His superiors, however, noting his natural talent for the sciences, advised him to pursue studies in physics, mathematics, and geology. He graduated with the Master's degree in 1911.

In 1921 he undertook further studies in these same fields at the University of California in Berkeley. There in 1923 he took his Ph.D. While his major was in physics with minors in geology and mathematics, his dissertation was in seismology. At the special request of the director of the department of geology, he stayed two more years at the University of California as assistant professor in geology to organize graduate studies in geophysics. He was placed in complete charge of the university's earthquake observatories located at Berkeley and on Mount Hamilton.

In 1925 he left the University of California to establish at Saint Louis University the first department of geophysics in the western hemisphere. Here his initial research centered around seismology as related to earthquakes. Ten years later we find that some of his time was being taken up by the measurement of industrial vibrations and their possible cause of damage to man-made structures.

By 1940 several classes at the university had already been graduated with undergraduate majors in exploration geophysics.

As he expanded the work of the department to include geophysical exploration he also added courses in meteorology. Thus, with the passing years he widened the scope of geophysical education at the University.

Besides developing the department of geophysics in its course offerings and in its research projects, he was dean of the university's graduate school from 1927 to 1933 and a member of the board of trustees. In 1944 he established and was the first dean of the Institute of Technology which sponsors curricula in engineering and in the earth sciences. Up to the time of his death he managed to teach one or more classes in spite of his membership in many University committees and labors in numerous scientific organizations of local and national character. He wrote two books, contributed several chapters to others, and wrote 133 technical papers for various learned journals.

In 1925 he was the prime mover in establishing both the Jesuit Seismological Association and the Eastern Section of the Seismological Society of America. He served these two organizations as president. At the time of his death he was completing the second of the three-year term as president of the American Geophysical Union. In 1948 the William Bowie Medal was bestowed on him by the American Geophysical Union for outstanding research in geophysics.

Other honors came to him. He received four honorary degrees, received the Villanova University Mendal Medal, and the Jackling Lecture Award was given him by the American Institute of Mining and Metallurgical Engineers. His stature as a scientist was recognized in that he was made a fellow of the Geological Society of America, of the American Physical Society, of the American Geographical Society, and the American Association for the Advancement of Science, and was elected a member of the National Academy of Sciences.

Father Macelwane's association with the society of Exploration Geophysicists began with his membership in the society in 1936. Because of his deep interest in geophysical exploration he participated actively in the work of the Society. From 1946 to the time he died he was chairman of the Standing Committee on Geophysical Education, and published in 1950 the first Annual Survey of Geophysical Education. In 1955 he was made a member of the society's Special Committee on Research. His contribution to the work of the society was recognized in his being made an honorary life member at the twenty-fifth annual meeting held in October, 1955.

Always willing to share his knowledge and experience, his services were in constant demand. In 1947 he was appointed to the Research and Development Board of the Department of Defense. Some years later he became a member of the Scientific Advisory Board of the United States Air Force. In 1952 he was numbered among the members of the Committee on Institutional Research Policy of the American Council on Education. Two years later President Eisenhower's appointment placed him on the National Science Board of the National

Science Foundation. As the program of the International Geophysical Year developed he was made chairman of the United States Technical Panel on Seismology and Gravity.

To perform these many labors he could be found in his office in the early morning and late at night. His daily routine included time for his religious duties as a member of the Jesuit community at Saint Louis University where he lived after his return from the University of California in 1925. He had little interest in sport events, playing of cards, or seeing of movies, but local and national news as well as certain sections of the comic strips he followed with daily regularity. A day spent geologizing in the field was particularly delightful to him. Always friendly and a good community man, his colleagues called him "Father Mac." His renown as a scientist did not place a barrier between himself and others. Students felt free to call on him for advice. His ready smile greeted a person with such sincere friendliness that one could not help but be at ease with him.

His remarkable capacity for getting many and different things done was greatly aided by his robust health. His endurance, whether in giving students their first taste of field geology in the foothills of the Colorado Rockies, or in working late into the night, or in being prepared for hard work immediately after a prolonged and fatiguing trip amazed his younger confreres. In the fall of 1954, however, a change came over him. He appeared tired and lacked zest. Nevertheless, a checkup in the hospital revealed nothing to cause concern.

A year later he again returned to the hospital. An exploratory operation in December, 1955, indicated acute necrosis of the liver. Intensive medication seemed to improve his condition for awhile but by the beginning of February his decline was very rapid. All admired the unusual patience and good humor with which he bore his physical discomforts and the many weeks of hospital inconveniences. When death came on February 15, 1956, the very numerous telegrams and letters from all parts of the world almost in unison mourned not only the passing of a great scientist but the loss of a noble and much beloved person.

VICTOR J. BLUM, S.J.

October 12, 1956

MEMORIAL

MORRIS MILLER SLOTNICK

Morris Miller Slotnick died suddenly of a heart attack on May 7, 1956, in Dallas, Taxas. He was at the Love Field Airport on his way to board a plane at the time he was stricken and he never regained consciousness. Moe, as he was affectionately called by his many friends, was very widely known in the geophysical fraternity. He had been for many years a shining light in this field and his untimely death is a grievous blow to all who knew him.

Moe was born in Zelva, Russia, in 1901 and moved to the United States with his parents at the tender age of 2. He grew up in Lawrence, Massachusetts, and Bridgeport, Connecticut, and by the time he was ready for college had decided on mathematics as his field and on Harvard as the university of his choice. His scholastic record at Harvard was outstanding. He received his bachelor's degree in 1922 and continued his studies, receiving the degree of doctor of philosophy in mathematics in 1926.

Following completion of his doctoral work at Harvard, he married Esther Joselle of Boston and the two promptly departed for Europe where Moe spent

a year in post-doctoral studies as a Harvard Traveling Research Fellow at the University of Hamburg. Then followed, at yearly intervals, posts of National Research Fellow at Princeton, mathematics instructor at Harvard, and assistant professor of mathematics at Grinnell College. He joined the Humble Oil & Refining Company in 1930 as a research mathematician in the geophysical department and continued in this work becoming chief mathematician for Humble in 1949. During the war he served with the Naval Ordnance Bureau in Washington, D. C., and was engaged in mathematical studies of the type that have since become well known as operations research. In 1954 he transferred from Humble to the Standard-Vacuum Oil Company as geophysics consultant and advisor which position he held at the time of his death.

Moe was a brilliant mathematician as well as a man of broad cultural and humanitarian interests. His was a stimulating intellect coupled with a friendliness and frankness that attracted all who met him. He was particularly interested in the training of younger men and one of his most enjoyable duties at Humble was the giving of instruction to young geophysics computers and interpreters.

He was the author of numerous papers dealing with geophysical interpretation, and many computing procedures which he developed have been extensively used. As editor of GEOPHYSICS in 1937 and 1938 he worked hard at improving the technical stature of the journal. His enthusiasm and energy did much to attract good papers in those days when the society was struggling along at less than one-fourth of its present size.

Moe maintained throughout his career a close attachment to academic circles, particularly in the field of mathematics. He was for years a member of the Visiting Committee on Mathematics for the Board of Overseers at Harvard—a post of distinction which he still held at the time of his death.

Moe is survived by his wife, Esther, and by two children, a daughter, Jane Slotnick Freeman, and a son, Joseph. His passing is a loss which is deeply felt. He was loved and will be long remembered by all those whose privilege it was to know him.

R. R. THOMPSON

CONTRIBUTORS

BIMAL KRISHNA BHATTACHARYYA

BIMAL KRISHNA BHATTACHARYYA received a B.Sc. degree in Mathematics in 1949 and an M.Sc. degree in Radio-Physics and Electronics in 1951 from the University of Calcutta, India.

During the years 1952–54 he worked as a member of the team for the erection of the Cyclotron of the Institute of Nuclear Physics, Calcutta University. At that time he carried out some investigations on pulse amplifiers and their associated networks. During 1954–55 he was employed as a Senior Research Assistant at the Geophysical Laboratory of the Indian Institute of Technology, Kharagpur, India, where he was mainly concerned with problems on electromagnetic induction and propagation below the surface of the earth. He is at present a Lecturer in the Institute of Radio-Physics and Electronics, Calcutta University.

He is a member of the Indian Association for the Cultivation of Science and an Associate member of the Institute of Radio Engineers (U.S.A.).

R. A. BLACK

R. A. BLACK was born in St. Louis, Mo. in 1924. He served in the U. S. Air Force as a Communications Officer during 1943–1946, and then entered Washington University, from which he received the degree of B.S. in Geological Engineering in January 1951. From June 1951 until the present he has worked as a geophysicist with the U. S. Geological Survey. From 1951–1952 he worked on geothermal studies of permafrost in Alaska and from that time to the present he has been concerned with geophysical studies of uranium deposits in the western U. S. In January 1955 he received the M.A. degree from Washington Universty in geophysics. Mr. Black is a member of the Society of Exploration Geophysicists, Tau Beta Pi, The American Geophysical Union, and the European Association of Exploration Geophysicists. He is an associate member of Sigma Xi.

LEENDERT DE WITTE

LEENDERT DE WITTE did his undergraduate work in geology at the University of Groningen, Holland. He escaped from occupied Holland in 1943 and spent three years in the infantry of the Netherlands East Indies Army. In 1947, he received his M.Sc. in geophysics from the California Institute of Technology. After a year with Surenco in Venezuela, he returned to Cal Tech and received his Ph.D in geophysics and petroleum geology in 1950. From 1951 till 1955 he was with the Research Department of Continental Oil Company; first as group leader for Well Logging Research, later as supervisor of the physics section of Production Research. Since April 1955, he has been a consultant in applied research and petroleum exploration, located in Laguna Beach, California.

KENNETH P. FOURNIER graduated from the Colorado School of Mines with an engineering degree in Geophysics in 1953. He worked for a short time with the Navy at the Puget Sound Naval Shipyard in Bremerton, Washington, where he studied some vibration analysis techniques. In December of 1953 he was drafted into the army, and served for two years in the Medical Service Corps. Upon discharge from the armed forces he was employed by the Lane-Wells Company where he is currently engaged as a geophysical engineer in Electrical Well Logging Interpretation Studies.

KENNETH P. FOURNIER

L. F. IVANHOE

L. F. IVANHOE received the B.S. degree in mining engineering in 1942 and the E.M. degree as Engineer of Mines in 1947, both from the South Dakota School of Mines. After receiving the M.S. in geology from Stanford University in 1949 he studied law for two years. From 1942 to 1948 Mr. Ivanhoe worked two years in mining engineering in Ecuador and four years in various geology-geophysics positions, including all field positions through supervisor, with contract companies in the United States, Venezuela, Canada, and in review geophysics with the Venezuelan Atlantic Refining Company. From 1949 to 1954 he was employed by Standard Oil Company of California where he organized the gravity-magnetics division. He was supervisor and interpreter of offshore seismic work, supervisor of the Central California geophysical operations, and taught geological interpretation of geophysical data. Since 1954 he has been exploration geologist for Franco Western Oil Company, Bakersfield, California.

Mr. Ivanhoe is a member of The American Association of Petroleum Geologists, and has been a member of the Society of Exploration Geophysicists since 1946.

J. BURLIN JOHNSON, JR.

J. BURLIN JOHNSON, JR. received an A.B. degree in mathematics from Cornell University in 1950. From 1950 to 1952 he worked as a mathematician; for three months at the Ryan Aeronautical Co. and for 21 months at the Martin Aircraft Co. while in the U. S. Army. In 1953 he entered the New Mexico Institute of Mining and Technology, receiving an M.S. degree in geophysics in 1954. He continued graduate work at the University of Utah, receiving the Ph.D. degree in geophysics in August, 1956. He is now working for the Richmond Exploration Co. in Maracaibo, Venezuela.

Mr. Johnson is a member of Sigma Xi and a student member of the Society of Exploration Geophysicists. (He has applied for Associate Membership.)

PAUL E. KLOPSTEG

PAUL E. KLOPSTEG in a long and varied career has served as college professor, president of a scientific company, government authority on science and research in war and peace.

Born in Henderson, Minnesota, he received his undergraduate and Ph.D. degrees from the University of Minnesota and served on the physics faculty there prior to America's entry into war in 1917. He was a development engineer with the Ordnance Department of the Army in that conflict and later became a physicist with the Leeds and Northrup Company.

He was successively director of research and manufacturing and president of the Central Scientific Company in Chicago. He also was Professor of Applied Science at Northwestern University from 1944 to 1954.

During World War II, he was both Deputy Chief of the Instruments Section, National Defense Research Committee and Chief of Physics for the Special Devices Division. From 1944 to 1945 he was Assistant Chief of the Office of Field Service, Office of Scientific Research and Development. He was Chairman of the Committee on Artificial Limbs of the National Research Council, and Chairman and a member of the Board of Governors of the Argonne National Laboratory, 1949 and 1950. He received the Modern Pioneers Award of the National Association of Manufacturers and the Presidential Medal for Merit.

He received honorary degrees both from Northwestern and Wesleyan Universities.

In addition to his membership in several scientific societies, he served both as president and treasurer of the American Association of Physics Teachers.

HOMER G. PATRICK received his B.S. degree in Electrical Engineering from The Rice Institute in 1925. Immediately following graduation he was employed by Humble Oil & Refining Company in its Exploration Department. His early training was as a member of a seismic field crew. He served as Party Chief from 1927 to 1934 when he was put in charge of all Humble's Seismic exploration work. In 1955 he was made Chief Geophysicist for that company. He is a member of the Society of Exploration Geophysicists and its Houston Section, having joined the Society in 1935.

HOMER G. PATRICK

ADRIAN E. SCHEIDEGGER

ADRIAN E. SCHEIDEGGER is a native of Switzerland and received his undergraduate training in theoretical physics at the Swiss Federal Institute of Technology in Zurich. In 1948 he won a Swiss-Canadian Students Exchange Fellowship that enabled him to take his Ph.D. in Applied Mathematics at the University of Toronto. Subsequently, he was on the staff of Queen's University in Kingston, Ontario, for two years teaching physics to engineering students. From 1952–1954 he was employed by the Engineering Laboratory of Imperial Oil Limited in Calgary, Canada, doing research in various branches of geophysics. In 1954 he joined the Dominion Observatory in Ottawa, Canada, where he is engaged in research in seismology.

Dr. Scheidegger has been active in theoretical geophysics. He has written various research papers on geodynamics as well as a book on "The Physics of Flow through Porous Media." He is a member of the American Physical Society, the Seismological Society of America, the Canadian Mathematical Congress, the Canadian Association of Physicists and a Junior Member of the Canadian Institute of Mining and Metallury.

LUIS HERNAN TEJADA-FLORES

LUIS HERNAN TEJADA-FLORES was born in La Paz Bolivia. He took his doctorate in Electrical Engineering at the California Institute of Technology in Pasadena, in 1948. He was a Guggenheim Research Fellow at the same institution the following year. Until 1953, he taught in the Electrical Engineering Department of the University of Southern California in Los Angeles.

From 1953 to 1954, he was associated with the Research Department of the United Geophysical Co. in Pasadena; and for the last three years, he has been with Lane-Wells Co. in Los Angeles, as Senior Geophysical Engineer.

At present, he is a member of the Research and Development Department of the Micronics Division of Zenith Plastics Co. in Gardena, California.

Dr. Tejada-Flores is a member of the American Institute of Electrical Engineers, the Institute of Radio Engineers, the Society of Exploration Geophysicists, the European Association of Exploration Geophysicists, the Society of Industrial Mathematics, the Society of the Sigma Xi, and Eta Kappa Nu.

PATRICK L. WILLMORE

PATRICK L. WILLMORE is a native of England and graduated in Physics from the University of Cambridge in 1942. He spent the next three years on wartime research projects. After the war he returned to Cambridge to obtain his Ph.D. He made journeys to study the seismic waves produced by the demolition of the fortifications on Heligoland and the rockbursts in the Johannesburg (South Africa) gold mining area. He also designed portable seismographs for field use, and assisted in a submarine gravity survey of the Eastern Mediterranean. In 1952 he joined the staff of the Dominion Observatory, Ottawa, where he has devoted most of his time to crustal studies.

He is a member of the Canadian Association of Physicists and of the Seismological Society of America.

Biographies and photographs of the following authors appear in recent issues of GEOPHYSICS: D. S. HUGHES, v. 21, p. 506; CHRISTIAN MAURETTE, v. 21, p. 507; L. C. PAKISER , v. 21, p. 508

SOCIETY ROUND TABLE

COMMITTEES FOR THE YEAR ENDING IN NOVEMBER, 1957

EXECUTIVE COMMITTEE

President: ROY F. BENNETT, Sohio Petroleum Co., Oklahoma City, Oklahoma
Vice-President: J. P. WOODS, The Atlantic Refining Co., Dallas, Texas
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Editor: NORMAN RICKER, The Carter Oil Co., Tulsa, Oklahoma
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PAUL L. LYONS

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Radioactive Mineral Exploration

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Paul L. Lyons ('57)
R. C. Dunlap, Jr. ('58)

Business Office

H. M. Thralls, *Chairman*
Craig Ferris
James F. Johnson

National Research Council Div'n of Earth Sciences Representative

(To be appointed)

AAAS Council Representative

Roland F. Beers

LOCAL SECTIONS

Geophysical Society of Tulsa

Chartered February 2, 1948

Pres.: W. M. Erdahl
1st V-Pres.: John J. Rupnik
2nd V-Pres.: James F. Johnson
Treas.: John E. Bondurant
Editor: V. L. Jones
Secty.: Ralph D. Lynn
The Carter Oil Company
Box 801
Tulsa 2, Oklahoma
Meetings: Monthly, 2nd Thursday
7:00 P.M., meeting only
University of Tulsa, room 224,
Petroleum Science Hall

SEG Houston Section

Chartered February 14, 1948

Pres.: W. B. Lee, Jr.
1st V-Pres.: Otis B. Hocker
2nd V-Pres.: Curtis P. Harkins
Treas.: J. D. Watzlavik
Secty.: Ben R. Howard
Warren Petroleum Corp.
801 1st City Nat'l Bank Bldg.
Houston 2, Texas
Meetings: Monthly
Noon luncheon ($1.65)
Rice Hotel

Pacific Coast Section SEG

Chartered April 12, 1948
Pres.: Flint H. Agee
V-Pres, N.D.: C. A. Bengston
V-Pres. S.D.: Lawrence S. Morrison
Secty.: John A. Hugus
Western Gulf Oil Co.
900 Wilshire Blvd.
Los Angeles 17, Calif.
Meetings: Monthly, 2nd Thursday
Noon luncheon ($2.00)
Biltmore Hotel, Los Angeles

Dallas Geophysical Society

Chartered August 7, 1948
Pres.: R. E. Rettger
1st V-Pres.: Chester Donnally
2nd V-Pres.: A. W. Musgrave
Secty.: Wm. C. Wooley
Magnolia Petroleum Co.
Box 900
Dallas, Texas
Meetings: Monthly, usually 2nd Monday
8:00 P.M.
Fondren Science Building
Southern Methodist University

Fort Worth Geophysical Society

Chartered August 7, 1948
Pres.: A. E. McKay
V-Pres.: R. C. Herron
Secty.: V. S. Balderson
The Pure Oil Co.
Box 2107
Forth Worth, Texas
Meetings: Monthly, 4th Monday
Noon luncheon ($1.50)
Texas Hotel

Ark-La-Tex Geophysical Society

Chartered March 12, 1949
Pres.: Herbert J. Ferber
V-Pres.: Charles P. Bragg
Secty.: H. L. Grant
Western Geophysical Company
980 Jordan Street
Shreveport, Louisiana
Meetings: Monthly, last Monday
Noon luncheon ($1.50)
Captain Shreve Hotel
Shreveport

Permian Basin Geophysical Society

Chartered January 30, 1950
Pres.: Decker Dawson
1st V-Pres.: Maxey Pinson
2nd V-Pres.: W. A. Seal, Jr.
Treas.: R. J. Knott
Stanolind Oil & Gas Company
Box 1540
Midland, Texas
Meetings: Monthly, 2nd Tuesday
7:30 P.M., free coffee & donuts
Midland Womens Club
Midland, Texas

Denver Geophysical Society

Chartered May 19, 1950
Pres.: E. B. Wasson
V-Pres.: C. E. Riddell
Secty.: R. R. Parks
The Chicago Corporation
333 Logan Street
Denver, Colorado
Meetings: Monthly, 1st Monday
5:30 P.M., meeting only
Petroleum Club, Denver

Canadian SEG

Chartered January 24, 1952
Pres.: Ralph B. Ross
V-Pres.: George J. Blundun
Secty.: Don V. Bigelow
Mobil Oil of Canada Ltd.
Mobil Oil Building
Calgary, Alberta
Meetings: Monthly, no set schedule

Geophysical Society of Oklahoma City

Chartered September 30, 1952
Pres.: John Bemrose
1st V-Pres.: W. B. Robinson
2nd V-Pres.: D. D. Moore
Treas.: Ben W. Smith
Secty.: George E. Anderson
Stanolind Oil & Gas Co.
Box 1654
Oklahoma City, Oklahoma
Meetings: Monthly, 2nd or 3rd Monday
Time and place to be announced

Casper Geophysical Society

Chartered May 23, 1953
Pres.: W. N. Farmer
V-Pres.: H. F. Dodson
Secty.: C. M. Brown
Teton Tool Company
Box 338
Mills, Wyoming
Meetings: Monthly, 1st Monday
7:00 P.M., dinner ($2.75)
Townsend Hotel
Casper, Wyoming

Geophysical Society of South Texas

Chartered November 9, 1953
Pres.: W. Lee Moore
V-Pres.: William R. Gray
Secty.: Dillon S. Frazier
Petty Geophysical Engg. Co.
Transit Tower
San Antonio, Texas
Meetings: 1st and 3rd Wednesdays
Noon luncheon, Sommers Cafeteria
Main Plaza, San Antonio

Southeastern Geophysical Society

Chartered April 1, 1954
Pres.: John F. Boyd
V-Pres.: O. G. Holekamp
Secty.: R. E. Halsey
Sinclair Oil & Gas Co.
860 St. Charles Ave.
New Orleans, Louisiana
Meetings: Monthly, 3rd Monday
Noon luncheon ($1.50)
St. Charles Hotel
New Orleans

Montana Geophysical Society

Chartered April 12, 1954
Pres.: Sam Marsh
1st V-Pres.: Jack Peters
2nd V-Pres.: M. D. Wickerham
Secty.: C. F. Moore
Sohio Petroleum Company
Box 2558
Billings, Montana
Meetings: Monthly, 2nd Monday
7:30 P.M., Billings Petroleum Club
Billings, Montana

Jackson Geophysical Society

Chartered May 12, 1955
Pres.: Fred Forward
V-Pres.: W. J. Robinson
Secty.: R. Long
Stanolind Oil & Gas Co.
1166 Raymond Road
Jackson, Mississippi
Meetings: Monthly, during 3rd week
5:30 P.M., refreshments
6:30 P.M., dinner ($2.00)
Roof Garden of Robert E. Lee Hotel
Jackson, Mississippi

Southwest Louisiana Geophysical Society

Chartered January 4, 1956
Pres.: J. J. Schneider, Jr.
1st V-Pres.: E. L. Ricketts
2nd V-Pres.: E. L. Current
Secty.: J. W. Bell, Jr.
Pan-American Production Co.
Drawer 1409, Oil Center Station
Lafayette, Louisiana
Meetings: to be announced

Dakota Geophysical Society

To be chartered
Pres.: W. E. Phillips
1st V-Pres.: Hugh McCain
2nd V-Pres.: Quin Hayes
Secty.: R. R. Phair
Roundup Powder Company
Box 452
Bismarck, North Dakota
Meetings: Monthly, 1st Friday
7:30 P.M., Petroleum Club
Prince Hotel
Bismarck, North Dakota

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STUDENT SOCIETIES

(Affiliated)

Colorado School of Mines Society of Student Geophysicists

Secty.: John M. Perrigo
Department of Geophysics
Colorado School of Mines
Golden, Colorado
Meetings: to be announced

Geophysical Society of Saint Louis University

Secty.: Thomas McEvilly
Saint Louis University
3621 Olive Street
St. Louis 8, Missouri
Meetings: Monthly, 2nd Wednesday
7:30 P.M., meeting only
Institute of Technology

SEG Houston Student Section

Secty.: D. H. Cook
University of Houston
Houston, Texas
Meetings: to be announced

University of Toronto Geophysical Society

Secty.: John E. Hogg
49 St. George Street
Toronto 5, Ontario
Meetings: Bi-weekly, alternate Thursdays
4:00 P.M., 49 St. George Street

University of Tulsa Student Geophysical Society

Secty.: Pat Doby
Department of Geophysics
600 South College
Tulsa, Oklahoma
Meetings: Weekly, Thursday
4:00 P.M., Petroleum Science Bldg.

Trans-Pecos Student Section

Secty.: John T. Sample, Jr.
Box 56
Texas Western College
El Paso, Texas
Meetings: to be announced

Pennsylvania State University Geophysical Society

Secty.: James B. Imswiler
College of Mineral Industries
University Park, Pa.
Meetings: to be announced

University of Utah Geophysical Society

Secty.: Howard L. Confer
College of Mines and
Mineral Industries
Salt Lake City 1, Utah
Meetings: Monthly, 1st Thursday
Noon, Mines Building
Other special meetings to be announced

Georgia Institute of Technology, Geophysical Society

Secty.: William Hogarth
Box 4748
Atlanta, Georgia
Meetings: to be announced

MEMBERSHIP APPLICATIONS RECEIVED

Applications for Active membership have been received from the following candidates. This publication does not constitute an election but places the names before the membership at large, in accordance with Bylaws, Article III, Section 4. References are listed in parentheses following the name of each candidate. If any member has information bearing on the qualifications of these candidates he should send it to the President within thirty days.

APPLICATIONS FOR ACTIVE MEMBERSHIP

Joe E. Allen (A. M. Olander, Robert C. Stone, B. M. Crow)
F. D. Barnett (D. M. Denton, R. D. Arnett, C. G. McBurney, J. T. Lodge)
Dearal W. Beddo (Earle Wright, Malcolm Knock, R. A. Gilmore, J. L. Mataya)
R. D. Brace (C. A. Bengtson, J. W. Mathews, S. C. Stoneham)
Wm. M. Brodrick (B. F. Murphy, J. T. Lodge, J. W. Gaither, James Divelbiss)
Antonino Bucarelli (Michael A. Boccalery, Thomas P. Maroney, Fred T. Kafka)
Charles E. Caldwell, Jr. (A. J. W. Kovak, R. L. Gallaway, B. H. Treybig)
G. C. Carpenter (W. H. Dawson, G. E. Olson, R. W. Jackson, M. A. Young)
Elwyn M. Creel (B. H. Treybig, Jr., R. W. Wilkinson, Alf Klaveness, H. W. McDonnold)
N. M. Ediger (R. B. Ross, H. J. McGrew, R. J. Copeland, S. G. Pearson)
F. H. Ellgring (H. R. Drummond, R. R. Taylor, J. B. Prendergast, J. S. Dowsett)
Ivan Engel (S. P. Weatherby, J. Scheffler, L. Cagniard)
Charles W. Frobese (J. P. Anthony, D. D. Mize, P. C. Sundt)
M. Gallinaro (J. F. Thompson, A. Farando, A. Frey)
Victor D. Garrett (M. O. Duke, John R. Foster, W. C. Wagner, E. Thomsen)
Harry D. Gibbs (Delbert Smith, Warren Collins, Robert Cole, George Gibson)
A. Ginzburg (C. L. Pekeris, M. I. Behr, Louis Franklin)
Wm. R. Goodey (E. L. Fetzer, W. K. Rickel, H. M. Houghton)
F. A. Hanning (A. P. Crosby, H. W. Stoneman, G. C. Agnew)
T. N. Hatfield (R. A. Geyer, Fred Romberg, George Sommers, Noyes Smith, Jr.)
Charles C. Hogue (H. F. Patterson, F. E. Wright, D. W. Ratliff)
C. W. Hunt (Bruce McDougall, T. A. Link, Peter Bediz)
J. M. Jacksom, Jr. (G. O. Morgan, C. S. Fleischmann, J. B. Meitzen)
Roy K. Keel, Jr. (B. M. Crow, C. S. Fleischmann, G. O. Morgan, A. P. Wendler)
L. F. Kihneman, Jr. (G. W. Isensee, J. A. Lester, J. C. Eley, A. W. Musgrave)
Harold L. Metz (Paul Conrad, J. B. McKee, Paul LeTourneau)
J. Millouet (Lucien Beaufort, Paul Giraud, Claude Aynard)
Charles H. Moore (Arthur A. Moore, Jr., R. P. Warren, J. C. Porter)
James M. Murphy, Jr. (R. A. Hartenberger, S. A. Spencer, J. A. Standridge, E. S. Hastings)
W. H. Parker, Jr. (A. L. Ladner, C. C. Zimmerman, W. C. Kimball, Sidney Schafer)
Ralph A. Paulus (Frank Ittner, J. E. Jones, Cecil E. Reel, C. R. Partridge)
Orley E. Prather (Paul E. Swenson, J. F. Fuller, W. H. Morgan)
M. W. Richard (B. H. Treybig, Jr., R. W. Wilkinson, L. W. Cobena, J. J. Schneider, Jr.)
Frank A. Rotramel (R. W. Keeling, F. P. Kokesh, K. R. Beeman, Jack Bulhon)
Don A. Saunders (R. C. Roesch, J. P. Antony, Jr., D. D. Mize)
Robert M. Specht (Homer Roberts, Paul Greenlee, Adelbert Kohler, A. W. Black)
Fonza A. Smith (D. P. Melton, R. S. Duty, C. F. Wendenburg, R. N. Ostriem)
Gerald J. Sykes (T. Rozsa, E. E. Rutledge, D. A. MacDonald)
George W. Taylor (E. L. Campbell, J. G. Frasher, R. A. Boulware, W. R. Mitchel)
Arthur L. Watson (Burton McCollum, R. L. Palmer, L. E. Twining)
Homer F. Wilson, Jr. (Leo Markley, G. O. Morgan, R. A. Lowery)
Roy A. Wilson (R. F. Weichert, Marvin Romberg, J. M. Watson, W. H. Josselyn)
M. C. Woodward (R. F. Keller, T. A. Hallbrook, Harold Farney, D. H. Parry)

APPLICATIONS FOR TRANSFER TO ACTIVE MEMBERSHIP

Noel C. Burke (T. O. Hall, Jack Martin, Charles B. Cox)
Julian M. Busby (John Norden, David Reed, William H. Pine)
William J. Cunningham (T. S. Green, H. M. Thralls, William J. Robinson)
Guy W. Franson (B. J. Borning, H. G. McCleary, W. L. Homan)
Michael R. Owens (W. H. Hawkes, G. L. Ellis, H. A. Willis)
John C. Pflueger (F. J. Agnich, R. Dyk, D. Rockwell)
Leo Rodgers (R. C. Clark, R. F. Weichert, G. G. Walton)
C. R. Wedin (H. J. Kidder, D. V. Bigelow, L. Castelli, D. E. Dalik)

TWENTY-SEVENTH ANNUAL MEETING

John P. Woods, SEG Vice President and ex officio responsible for the National Meeting arrangements, announced the appointment of Fred J. Agnich as General Chairman of the 27th Annual Convention to be held in Dallas at the Statler-Hilton Hotel, November 10–15, 1957. Mr. Agnich is President of Geophysical Service Inc. and headquarters in Dallas.

The following appointments have been made thus far by Mr. Agnich:

Assistant General Chairman and Chairman of Finance Committee, E. O. Vetter, Dallas, Administrative Vice President of Geophysical Service Inc.

Chairman of Technical Program Committee, Glen M. Conklin, Seismograph Section Head, Southwestern Division, Sun Oil Company, Dallas.

Chairman of Publicity, Charles J. Deegan, Petroleum Consultant, Dallas.

Chairman of the Exhibits Committee, John Cathey, Chief Geophysicist, Seaboard Oil Company, Dallas.

Chairman of Entertainment Committee, M. C. Kelsey, President, Rayflex Exploration Company, Dallas.

Chairman of Housing Committee, O. C. Clifford, Jr., Chief Geophysicist, The Atlantic Refining Company, Dallas.

Deadline for submittal of papers to Mr. Conklin for presentation at the meeting will be July 1, 1957.

Other appointments will be announced as soon as possible after men selected have been contacted and their acceptances are received.

PACIFIC COAST FALL MEETING

The annual fall meeting of the Pacific Coast Section of the Society of Exploration Geophysicists was held at the Ambassador Hotel in Los Angeles on Thursday and Friday, November 8 and 9, 1956. The meeting was held jointly with the Pacific Coast sections of the AAPG and SEPM.

At the Friday morning joint session, Mr. Joseph Kaplan, Professor of Physics at UCLA and chairman of the U. S. National Committee of the IGY, presented a geophysical paper of universal importance entitled "The International Geophysical Year."

Mr. P. F. Clement, Northern District Vice-President, Mr. L. K. Morris, Southern District Vice-President, and J. A. Hugus, SEG Program Chairman, presided at the Thursday morning technical session at which the following papers were presented:

1. "Methods of Filtering Seismic Data"—Mark K. Smith, Geophysical Service Inc.
2. "Wave Propagation in a Liquid Layer"—D. T. Liu, California Research Corporation.
3. "The Scattering of Body and Surface Waves by Topography"—L. Knopoff, UCLA.
4. "Model Studies of Bubble Dynamics in Offshore Shooting"—W. C. Knudsen, California Research Corporation.
5. "The Gulf Seismic Profile Printer"—E. M. Palmer, Gulf Research and Development Company.
6. "A Seismic Model Study of the Phase Velocity Method of Exploration"—Frank Press, California Institute of Technology

At the Friday SEG luncheon, Mr. Roy F. Bennett, National President, Society of Exploration Geophysicists, gave the main address. Mr. T. P. Ellsworth, Pacific Coast Section President of the SEG presided at the meeting and introduced the newly elected officers of the Pacific Coast Section as follows:

President:
Flint H. Agee
United Geophysical Corporation
1200 S. Marengo
Pasadena, California

Vice-President, Northern District:
C. A. Bengston
Standard Oil Co. of California
Box 278
Oildale, California

Vice-President, Southern District:
L. S. Morrison
Humble Oil Company
612 South Flower Street
Los Angeles 17, California

Secretary-Treasurer:
J. A. Hugus
Western Gulf Oil Company
1200 Statler Center
Los Angeles 17, California

District representatives elected for the 1956–1958 term are James A. Kurfess, Tide Water Associated Oil Company, Box 670, Bakersfield, California, and Robert E. Plumb, General Petroleum Corporation, 1825 19th Street, Bakersfield, California.

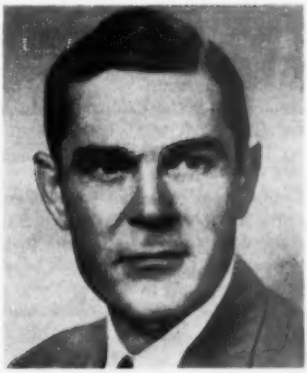
John A. Hugus
Secretary-Treasurer
Pacific Coast Section

November 15, 1956

OFFICERS FOR THE YEAR ENDING IN NOVEMBER, 1957

R. C. DUNLAP, JR., *Past President*

J. P. WOODS, *Vice-President*



ROY F. BENNETT, *President*

JOHN C. HOLLISTER,
Secretary-Treasurer

NORMAN RICKER, *Editor*

SOCIETY OF EXPLORATION GEOPHYSICISTS

ANNUAL REPORT

1955–1956

The purpose of this report is to furnish our members information about the activities of the Society in advance of the Annual Business Meeting to be held Monday afternoon, October 29, 1956. The reports of officers and committees that follow were reviewed by the Council prior to the Business Meeting.

The efforts of our officers and committees, and the cooperation of their companies, have continued the growth of the SEG in service to the science. Many other members have contributed without public recognition.

It was the privilege of the outgoing Vice-President on behalf of the President, to introduce the new officers of the Society at the Business Meeting, as follows.

President: Roy F. Bennett, Sohio Petroleum Company, Oklahoma City, Oklahoma
Vice President: John P. Woods, The Atlantic Refining Company, Dallas, Texas
Secretary-Treasurer: John C. Hollister, Colorado School of Mines, Golden, Colorado

Dr. Norman Ricker, The Carter Oil Company, Tulsa, Oklahoma, continues in his second year as Editor. Mr. Bennett will serve on the Executive Committee for one year as President and one year as Past President.

Our thanks are due also to the other nominees:
For President: Karl Dyk, Stanolind Oil & Gas Company, Tulsa, Oklahoma
For Vice President: E. V. McCollum, E. V. McCollum & Company, Tulsa, Oklahoma.
For Secretary-Treasurer: T. O. Hall, General Geophysical Company, Houston, Texas

The report of the Standing Committee on Education has been omitted, because a new chairman has not been appointed to succeed the late Rev. J. B. Macelwane, S.J.

I will always appreciate the high honor of serving as your President and the opportunity for first hand participation in the affairs of this dynamic Society.

R. C. Dunlap, Jr., *President*

Dallas, Texas
September 6, 1956

CONTENTS

Officers

President 180
Vice President 181
Secretary-Treasurer 181
Budget 184
Report of Auditors 185
Editor 190

Committees

Student Membership 192
Radio Facilities 195
Membership 195
Honor and Awards 197
Publications 197
Reviews 198

Publicity 198
Public Relations 199
Geophysical Activity 201
Safety 202
Case Histories 202
Constitution and Bylaws 203
American Institute of Physics 203
Research 204
Index of Wells 205
Magnetic Recording 206
Business Office 206
Distinguished Lectures 207

REPRESENTATIVES

Director of American Geological Institute 208
National Research Council 209
American Association for the Advancement of Science 211
Proposed "Annual Issue" 212

REPORT OF THE VICE PRESIDENT

As Vice President of the SEG for the period 1955–56, I have been concerned with the annual SEG Convention in New Orleans, the selection of a chairman for the convention to be held in Dallas in 1957, the selection for the site and the chairman for the 1958 convention, and the development of information which will lead to selection of a site for 1959.

Concerning the New Orleans Convention, preparations have been proceeding satisfactorily. The financial outlook for the Convention is satisfactory and more than a sufficient number of papers has been obtained to assure a good program at this meeting.

Concerning the 1957 Convention in Dallas, Mr. Fred Agnich has agreed to serve as chairman.

With regard to the selection of a site for the 1958 Convention, San Antonio has been selected and Mr. Weldon Crawford has agreed to serve as chairman.

There is not sufficient information at this time to report anything of importance on the selection of a 1959 site.

DAVE P. CARLTON, *Vice-President*

REPORT OF THE SECRETARY-TREASURER

The officers for the 1955–56 year began their term of office on October 5, 1955, during the annual Joint Council Meeting. Between that date and August 30, 1956, three Executive Committee Meetings were held, which were attended by all members.

A total of 68 Executive Orders were issued between October 5, 1955 and August 30, 1956. Of these, 48 related to change in membership status, membership applications, or resignations. Others were as follows:

No. 571—October 28, 1955—Appropriated funds for establishing a punched card file for tabulation of the Professional Interests survey of members.

No. 573—November 4, 1955—Designated the Midwestern Meeting of March 8 and 9, 1956, a Regional Meeting of SEG.

No. 574—November 8, 1955—Authorized presentation of a slide projector to the Denver Geophysical Society.

No. 575—November 8, 1955—Removed restrictions on sale of GEOPHYSICS to Soviet Bloc Countries.

No. 576—November 16, 1955—Authorized purchase of a Verifax copying machine.

No. 577—November 18, 1955—Established provision for SEG stationery to be supplied committees.

No. 578—November 21, 1955—Designated the Gulf Coast Meeting of May 17 and 18, 1956, a Regional Meeting of SEG.

No. 581—November 29, 1955—Chartered the Southwest Louisiana Geophysical Society as a local section.

No. 582—December 5, 1955—Authorized University Microfilms to microfilm GEOPHYSICS.

No. 585—December 6, 1955—Leased 1400 square feet in the AAPG Building at $3.25 per square foot per year for a five-year term to begin April 1, 1956.

No. 586—December 12, 1955—Purchase of $1,058.75 in office furniture and equipment.

No. 588—December 22, 1955—Authorized reprinting Early Geophysical Papers, subject to adequate demand.

No. 590—December 27, 1956—Authorized purchase of a noise reducing hood for the Graphotype machine.

No. 596—January 26, 1956—Affiliated with Georgia Institute of Technology Student Section of SEG.

No. 608—April 20, 1956—Approved amendments to the Oklahoma City Section Constitution.

No. 615—May 11, 1956—Purchased $474.51 in office furniture and equipment.

No. 626B—July 24, 1956—Approved a new contract with George Banta Company, Inc. for printing GEOPHYSICS.

No. 627—August 2, 1956—Appropriated $65.00 for erection of a sign to be placed on the SEG portion of the AAPG Building.

No. 630—August 15, 1956—Approved a new annual dues statement form.

No. 631—August 17, 1956—Revised the procedure for the Vice President for the Procedures Manual.

Meetings attended by the Executive Committee were: Joint Council Meeting on October 5, 1955, and Executive Committee Meetings on October 8, 1955, March 7, 1956, and July 20–21, 1956.

Actions taken by the Council and Executive Committee are listed below:

Annual Joint Council Meeting—October 5, 1955

1) Unanimously approved the actions of the Executive Committee during the period from the last Council Meeting and the Annual Reports of all Committee Chairmen.

2) Approved an amendment to the Constitution to provide for an increase in annual dues as follows: Active, $10.00 per year; Associate, $8.50 per year and $10.00 after a period of 5 years.

3) Decided to sell Volume II of Case Histories to SEG, AAPG, and AIME members for $6.00 and to all others at $7.00.

4) Approval was granted to the Sub-Committee on Mining Case Histories to continue to solicit papers for a Volume of Case Histories to be printed jointly with the EAEG.

5) Decided to continue active support of the AGI by making a contribution of $1,000.00 after July 1, 1956.

6) Approved the location and dates of the following annual meetings:

New Orleans, La., Oct. 29–Nov. 1, 1956
Dallas, Texas, November 10–15, 1957

7) Approved the Code of Ethics as printed in the October, 1954 issue of GEOPHYSICS.

8) Approved the action of the Honors and Awards Committee in selecting Cecil H. Green, Father James B. Macelwane, and Paul Weaver as Honorary Members.

9) Decided to adopt the Procedures Manual which was written for the guidance of officers.

10) Decided that only attending Representatives or Alternates may vote at Council Meetings.

11) Kenneth L. Cook was applauded for his excellent work in compiling the Cumulative Index of GEOPHYSICS (1931–1953).

Executive Committee Meeting—October 8, 1955

1) Approved adjustments in all Business Office staff salaries, effective October 1, 1955.

2) Authorized employment of a bookkeeper, bringing to five the total number of SEG employees.

Executive Committee Meeting—March 7, 1956

1) Signed a petition to the AIP requesting that SEG be admitted as a member society, as a result of a poll of all SEG members.

2) Adopted a resolution, to be published in GEOPHYSICS and to be sent to all local sections and geological societies, encouraging local geophysical sections and regional groups of sections to meet jointly with corresponding regional geological sections or groups.

3) Authorized Colin Campbell to attend the 1956 Annual Meeting of the Council of Engineering Society Secretaries, June 25–27, 1956 in Cincinnati, Ohio.

4) Recommended to the Constitution and Bylaws Committee that the Constitution be amended to provide for representatives at large to represent members who do not belong to local sections.

5) Approval was granted for Colin Campbell to attend the AAPG Meeting in Chicago, Ill., April 23–26, 1956 to man a booth displaying SEG publications which are for sale.

6) Approved publishing the year of affiliation for each member in the annual directory of members.

Executive Committee Meeting—July 20–21, 1956

1) Approved the holding of a Joint Council Meeting in New Orleans on October 29, 1956.

2) Approved changes in the Constitution and Bylaws as suggested by the Constitution and Bylaws Committee; major changes include:

a. Addition of sustaining members.

b. Provide for increase in subscription price of GEOPHYSICS.

c. To provide for the formation of local sections upon the petition of 20 members of any grade.

3) Approved the mailing of the January issue of GEOPHYSICS to all members whether or not their dues are paid by the date of publication.

4) Approved the appointment of Fred Agnich and Weldon Crawford as general chairmen for the 1957 and 1958 annual meetings.

5) Decided to recommend to the Council that an annual directory issue of GEOPHYSICS be published.

6) Authorized the reprinting of 1,500 copies of the volume of Early Geophysical Papers.

7) Approved maximum salary rates for business office employees which will compare favorably with similar positions in the industry.

8) Approved the investment of cash reserves of the society only in government bonds or savings and loan organizations limiting to $10,000.00 the amount to be invested in any one association.

9) Reduced the rental rate of the mailing list to $30.00 per thousand names.

10) Approved the 1957 budget showing an expected income of $117,000.00 and expenditures of $112,630.00 providing a net income of $4,370.00.

11) Approved the contribution of 10% of dues income ($4,300.00) for membership in AGI and AIP.

12) Authorized the Continental Casualty Company and the Fidelity Union Life Insurance Company to submit their plans for insurance for members to the Council for approval.

13) Authorized the business manager to solicit orders for bound copies of GEOPHYSICS beginning with Volume XXII at the rate of $6.00 per copy.

14) Authorized the business manager to solicit orders for reprinted bound copies of GEOPHYSICS Volumes IV, V and VI at a selling price of $6.00.

15) Instructed the business manager to recommend to all local sections that all of their publications, meeting programs, etc. be standardized to conform to the page size of GEOPHYSICS.

During the past, steps have been taken by the Executive Committee, which will, when they are placed in effect, allow an increase in the net income of SEG. These include the following:

a. An increase in dues
b. Strict supervision of convention income and expenses.
c. The creation of a Sustaining member type of membership.
d. The reprinting and sale of the Volume of Early Geophysical Papers.
e. Authorized a survey to determine the advisability of reprinting Volumes IV, V, and VI and offering them for sale.
f. Recommending to the Council that an annual issue of GEOPHYSICS be published to include the membership directory and other non-technical material and which will be self-supporting.
g. The rental rate of the mailing list was reduced to compare favorably with the rate for similar lists and active solicitation for its rental will be made.

Results of these steps will not be realized for some time; however, the Executive Committee feels that when the plans listed above are in operation that additional funds will be available for the use of future Executive Committees in the carrying out of useful projects even though they may not be self-supporting.

The accompanying Treasurer's report covers the fiscal year ending June 30, 1956, and presents an estimate of income and expense for the fiscal year ending June 30, 1957, subject to approval of the Council at its meeting on October 29, 1957. The financial statement, as approved by the auditors, shows the Society to be in an extremely sound financial condition and well able to undertake the publication of additional special publications which will return additional money to the Society.

The Secretary-Treasurer wishes to express his appreciation to all concerned, and especially to the Business Manager and his office staff who have helped make the term of office a great pleasure.

G. A. GRIMM

SOCIETY OF EXPLORATION GEOPHYSICISTS

COMPARATIVE STATEMENTS OF NET INCOME, 1953–1956

ESTIMATED NET INCOME FOR 1957

	1953	*1954 1st 6 Mo.*	*1954–1956*	*1955–1956*	*1956–1957 Estimate*
Income					
Membership dues	$30,281.50	$15,701.00	$34,413.60	$35,952.10	$ 43,000.00
Publications:					
GEOPHYSICS MAGAZINE					
Advertising	22,705.73	14,221.11	29,422.78	34,526.58	38,000.00
Subscriptions	7,252.58	3,362.88	7,100.00	8,171.00	9,000.00
Back Numbers	3,213.99	407.85	1,500.16	655.40	1,000.00
Microcards	361.00	91.07	232.90	220.10	200.00
Reprints	1,094.56	491.12	767.93	1,945.44	1,000.00
Early Geophysical Papers	—	—	—	—	4,000.00
Geophysical Case Histories, Vol. I	1,116.60	324.95	1,859.50	3,613.30	1,500.00
Geophysical Case Histories, Vol. II	—	—	—	—	14,000.00
Index of Wells Shot for Velocity	507.90	32.50	57.50	100.00	100.00
Careers in Expl. Geophysics	—	—	13,230.39	2,147.75	2,000.00
Cumulative Index	16.20	—	—	—	300.00
Bound Rep. of GEOPHYSICS, Vol. I, II & III	—	—	—	6,342.00	300.00
Discounts Allowed	(879.71)	(390.67)	(1,080.58)	(1,432.56)	(1,600.00)
Commissions on book sales	1,630.65	448.15	578.26	181.10	100.00
Mailing List rental	—	—	—	—	200.00
Commission on Microcard Readers	138.00	—	102.00	51.00	—
Annual Meetings	—	—	—	2,655.27	2,000.00
Safety Committee (Net)	(63.80)	1,501.70	(1,358.73)	1,272.83	1,000.00
Distinguished Lectures (Net)	(76.25)	(224.42)	(269.23)	380.76	100.00
Interests and Dividends received	500.43	171.71	314.93	573.46	500.00
Gain on sale of fixed assets	—	—	—	—	—
Other	576.46	407.44	1,434.54	507.51	500.00
TOTAL INCOME	$68,388.28	$36,546.39	$88,336.52	$97,033.14	$117,000.00

Less Expenses					
Publication costs					
GEOPHYSICS	$25,630.91	$14,640.37	$24,951.11	$36,827.05	$ 39,500.00
Bound Volumes	—	—	57.48	94.16	—
Microcards	288.19	557.75	—	22.67	100.00
Reprints	1,966.33	332.92	820.92	1,247.25	1,000.00
Bound Rep. GEOPHYSICS, Vol. I, II & III	—	—	—	5,506.76	—
Careers in Exploration Geophysics	—	—	15,215.87	2,087.88	—
Cumulative Index	—	—	—	904.10	—
Geophysical Case Histories, Vol. II	—	—	—	—	11,000.00
Early Geophysical Papers	—	—	—	—	4,000.00
Index of Wells Shot for Velocity	2,294.83	—	—	—	—
Contribution to other societies	—	—	—	—	2,000.00
Operating expenses	37,677.35	18,560.75	42,149.05	44,512.78	49,730.00
TOTAL EXPENSES	$67,857.61	$34,131.79	$83,195.03	$91,002.65	$110,330.00
Net Income	$ 530.67	$ 2,414.00	$ 5,171.49	$ 6,030.49	$ 6,670.00

REPORT OF AUDITORS

To the Executive Committee,
Society of Exploration Geophysicists

We have examined the balance sheet of the SOCIETY OF EXPLORATION GEOPHYSICISTS as of June 30, 1956 and the related statement of income for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances; however, in accordance with the terms of our engagement, we did not obtain confirmation of the accounts receivable, as to which we have satisfied ourselves by means of other auditing procedures.

In our opinion, the accompanying balance sheet and related statement of income present fairly the financial position of the Society of Exploration Geophysicists at June 30, 1956, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent (except for the change indicated in Note A, which change we approve) with that of the preceding year.

LYBRAND, ROSS BROS. & MONTGOMERY
CERTIFIED PUBLIC ACCOUNTANTS

Tulsa, Oklahoma
July 17, 1956

SOCIETY OF EXPLORATION GEOPHYSICISTS
BALANCE SHEET

JUNE 30, 1956 AND 1955

	1956	1955
ASSETS		
Current Assets:		
Cash	$38,849.10	$22,522.41
Accounts receivable (Note A):		
Membership dues	—	1,810.11
Advertising and other	4,294.78	5,479.73
	$ 4,294.78	$ 7,289.84
Less allowance for doubtful accounts	1,200.00	1,200.00
	$ 3,094.78	$ 6,089.84
Inventories (Note B):		
"GEOPHYSICS"	$ 8,384.00	$ 5,031.00
"Cumulative Index"	—	2,318.65
	$ 8,384.00	$ 7,349.65
TOTAL CURRENT ASSETS	$50,327.88	$35,961.90
Investments:		
United States Savings Bond, at cost	$14,040.00	$14,040.00
Stock of Container Corporation of America (market ($1,202.50)	466.75	466.75
	$14,506.75	$14,506.75
Fixed Assets:		
Office furniture and fixtures	$13,492.46	$11,560.83
Less allowance for depreciation	5,350.15	3,747.49
	$ 8,142.31	$ 7,813.34
Prepaid Expenses:		
Advance promotional costs (Note C):		
"Geophysical Case Histories, Vol. II"	$ 2,371.30	
"Early Geophysical Papers"	244.38	
Prepaid postage, insurance and other	2,045.68	$ 860.99
	$ 4,661.36	$ 860.99
	$77,638.30	$59,142.98

The accompanying notes are an integral part of the financial statements.

	1956	1955
LIABILITIES AND MEMBERS' EQUITY		
Current Liabilities:		
Accounts payable	$ 1,937.87	$ 1,058.01
Deferred Income		
Membership dues paid in advance	$18,500.35	$18,278.88
Subscriptions to and advertising in GEOPHYSICS paid in advance	4,625.75	4,165.75
Advance sales of special publications (Note C):		
"Geophysical Case Histories, Vol. II"	10,819.30	162.00
"Early Geophysical Papers"	1,176.00	
Reprints of "GEOPHYSICS," Vols. I, II and III		929.80
	$35,121.40	$23,536.43
Members' Equity:		
Balance at beginning of year	$34,548.54	$29,377.05
Net income for the year	6,030.49	5,171.49
Balance at end of year	$40,579.03	$34,548.54
	$77,638.30	$59,142.98

SOCIETY OF EXPLORATION GEOPHYSICISTS
STATEMENT OF INCOME

FOR THE YEARS ENDED JUNE 30, 1956 AND 1955

	1956		1955	
Income from Operations:				
Membership dues		$35,952.10		$34,413.60
Publications:				
GEOPHYSICS Magazine, etc.:				
Advertising	$34,526.58		$29,422.78	
Subscriptions	8,171.00		7,100.57	
Back numbers	625.40		1,560.16	
Microcards of back numbers	220.20		232.90	
Reprints	1,045.44		767.93	
	$44,588.62		$39,084.34	
Index of wells	100.00		57.50	
Geophysical Case Histories, Vol. I	3,613.30		1,859.50	
Reprints of GEOPHYSICS, Vols. I, II and III	6,342.00		—	
Vocational Guidance Brochure	2,147.75		13,230.39	
Commissions and discounts allowed	(1,332.56)	55,459.11	(1,870.70)	52,361.03
Commissions:				
Sales of books published by others	$ 181.10		$ 578.26	
Sales of microcard readers	51.00	232.10	102.00	680.26
Miscellaneous:				
Interest and dividends	$ 573.46		$ 314.93	
Annual meetings (net)	2,655.27		—	
Other	507.51	3,736.24	1,434.54	1,749.47
		$95,379.55		$89,204.36
Publication Costs and Expenses:				
Publication costs (Schedule I)	$46,489.87		$46,890.66	
Operating expenses (Schedule II)	44,512.78	91,002.65	35,514.25	82,404.91
Net income from operations		$ 4,376.90		$ 6,799.45
Safety Committee Operations:				
Income from sale of posters and subscriptions to Safety Committee publications	$ 3,783.05		$ 1,026.85	
Expenses—cost of printing and miscellaneous expenses	2,510.22		2,385.58	
Net income (loss) from Safety Committee operations		1,272.83		(1,358.73)
Distinguished Lecture Tours:				
Income from lecture tours	$ 975.00		$ 1,347.00	
Expenses of lecture tours	594.24		1,616.23	
Net income (loss) from lecture tours		380.76		(269.23)
TOTAL NET INCOME		$ 6,030.49		$ 5,171.49

The accompanying notes are an integral part of the financial statements.

SOCIETY OF EXPLORATION GEOPHYSICISTS
PUBLICATION COSTS AND OPERATING EXPENSES

FOR THE YEARS ENDED JUNE 30, 1956 AND 1955

PUBLICATION COSTS—SCHEDULE I

	1956		1955	
	Copies	*Amount*	*Copies*	*Amount*
GEOPHYSICS:				
July issue	6,500	$ 6,458.55	6,000	$ 6,832.58
October issue	6,500	7,407.73	6,000	6,587.00
January issue	7,100	8,107.15	6,500	6,003.56
April issue	7,100	8,697.20	6,500	6,119.78
Membership cut		2,723.19		2,164.19
Advertising commissions		6,786.23		5,845.28
		$40,180.05		$33,552.39
Less increase in inventory at June 30, 1956 and 1955		3,353.00		2,756.00
		$36,827.05		$30,796.39
Bound volumes		94.16		57.48
Microcards of GEOPHYSICS (back numbers)		22.67		
Reprints of GEOPHYSICS, Vols. I, II and III		5,306.76		
Reprints of GEOPHYSICS articles		1,247.25		820.92
"Vocational Guidance Brochure" (including cost of distribution)		2,087.88		15,215.87
Amortization of "Cumulative Index" expense		904.10		
		$46,489.87		$46,890.66

OPERATING EXPENSES—SCHEDULE II

Salaries	$19,363.76	$16,700.60
Office rent	3,090.51	2,604.00
Stationery and office supplies	6,422.18	4,427.35
Telephone and telegraph	1,026.11	558.28
Postage	5,303.92	3,925.98
Advertising expense	409.91	395.56
Traveling expense	403.65	323.59
Depreciation of office equipment	1,602.66	1,525.03
Provision for doubtful accounts, less recoveries	496.73	1,528.81
Payroll taxes	551.17	238.37
Audit expense	750.00	252.52
Insurance expense	295.08	261.77
Membership surveys	999.80	
Purchase of books published by others		592.49
Contribution to AGI	1,000.00	1,000.00
Other	2,797.30	1,179.90
	$44,512.78	$35,514.25

The accompanying notes are an integral part of the financial statements.

SOCIETY OF EXPLORATION GEOPHYSICISTS
NOTES TO FINANCIAL STATEMENTS
JUNE 30, 1956

(A) *Accounts Receivable:*

As of January 1, 1956, the Society discontinued the practice of accruing dues receivable from members at the beginning of the year and adopted the policy of recording dues when received. As of June 30, 1956, there were dues from delinquent members of approximately $1,800 which, if accrued, would have increased net income $900.

(B) *Inventories:*

Following the practice started in 1953, the Society values the quarterly issues of GEOPHYSICS for 1953 and subsequent years at $1 per copy which is approximate cost and lower than market.

The value of the inventories of GEOPHYSICS issued prior to 1953 and other publications, at their respective selling prices, is estimated to be approximately $21,000.00 at June 30, 1956. In accordance with the practice of prior years, these items have not been included in the balance sheets.

The inventory of the "Cumulative Index," published in the fiscal year 1955, is valued on the balance sheet at June 30, 1955, at the excess of publication costs over sales and advertising income from such publication. The unrecovered cost at June 30, 1956 in the amount of $904.10 has been charged to income in accordance with the Society's policy of writing off unrecovered costs of special publications at the end of the second year.

(C) *Special Publications:*

At June 30, 1956 the Society recorded as deferred income the advance sales of "Geophysical Case Histories, Vol. II" and "Early Geophysical Papers," and recorded as prepaid expenses the promotional costs applicable to these publications. The publication of the "Geophysical Case Histories, Vol. II" was completed in July, 1956. The estimated cost of printing is $12,400.00. The publication date for "Early Geophysical Papers" has not been scheduled.

REPORT OF THE EDITOR, 1955-1956

With this annual meeting of the Society the present editor completes the first year of his two-year tenure which began at the close of the 1955 annual meeting held in Denver, Colorado. This report describes the activities concerned with producing Volume XXI of GEOPHYSICS which consisted of four issues, January, April, July, and October. One of the first matters given attention was the date of issue of our journal. Through cooperation of our publishers, George Banta Company, Inc. of Menasha, Wisconsin we have been able to advance the date of issue from the last of the month of issue to the first of the month of issue. In spite of this earlier date of issue GEOPHYSICS has shown a healthy growth during the year as is indicated by the following table which shows a detailed breakdown of Volume XXI (1956) as compared with Volume XX (1955).

The present growth of our society membership is close to 7 percent per year. It is interesting to compare the growth of our journal, GEOPHYSICS, with this rate of growth of our membership. From 1955 to 1956 the number of technical pages in GEOPHYSICS has increased 22.4 percent. The number of technical papers (39 in 1955 and 48 in 1956) has shown an increase of 23.1 percent. The average length of technical papers has remained fairly constant being 15.6 pages/paper for 1955 and 15.5 pages/paper for 1956. Through attention to the published material other than technical papers, the rate of increase of this other material has been held down. Thus, while the number of pages of material other than technical in 1955 was 391 pages, it rose to only 422 pages in 1956 for an increase of 7.9 percent. The total pages in GEOPHYSICS increased from 998 in 1955 to 1165 pages in 1956 representing an increase of 16.8 percent. The total number of technical papers in 1956 was 48. During this same period, 12 papers were rejected. Thus, the 12 papers rejected represented 20 percent of the 60 available papers. The distribution of technical papers with respect to subject matter is shown in

PAGES OF MATERIAL IN GEOPHYSICS

	1955					1956				
	Jan.	*Apr.*	*July*	*Oct.*	*Total*	*Jan.*	*Apr.*	*July*	*Oct.*	*Total*
Presidential Address	—	—	13	—	13	15	—	—	—	15
Technical Papers	162	120	138	187	607	140	224	173	206	743
Index of Wells Shot for Velocity	—	—	—	—	—	23	—	—	—	23
Geophysical Activity	—	—	17	—	17	3	—	—	—	13
Patents	6	7	7	6	26	8	10	10	8	36
Reviews & Publications Received	7	7	11	6	31	9	4	8	6	27
Discussions & Communications	—	—	—	3	3	—	1	—	—	1
Memorials	2	4	2	—	8	2	4	8	—	14
Contributors	5	4	6	8	23	3	6	11	5	25
Committees	3	4	4	4	15	3	3	1	—	7
Local Sections	5	4	5	5	19	5	5	5	3	18
Meetings	8	11	7	—	26	1	30	—	—	31
Membership Applications	8	8	10	3	29	2	1	2	4	9
Annual Reports	—	8	2	7	17	31	—	—	—	31
Candidates for Executive Committee	—	4	—	—	4	—	4	—	—	4
Announcements	6	1	1	2	10	4	2	3	3	12
Personal Items	2	1	2	1	6	—	5	2	3	10
Constitutions & Bylaws	—	—	—	10	10	—	—	—	14	14
Other Non-Technical Papers	—	—	17	8	25	—	—	—	—	0
Calendar of Meetings	—	—	—	—	—	1	1	1	1	4
Membership List	—	105	—	—	105	—	120	—	—	120
Index	—	—	—	4	4	—	—	—	7	7
TOTALS	214	288	242	254	998	260	420	224	260	1,165

the following table for 1955 and for 1956. The two categories, seismic theory and seismic experiments, have been combined in this table because very often a given paper contains both experiment and theory.

The Editor wishes to express his warm appreciation to the many persons who assisted him in the carrying out of his editorial assignment. The six associate editors, C. Hewitt Dix, Milton B. Dobrin, Andrew Gilmour, Thomas A. Elkins, Robert G. Van Nostrand, and John Tuzo Wilson, have been most cooperative in handling the evaluation of manuscripts in their respective categories. Dr. John P. Woods and the other members of his Publications Committee, L. L. Nettleton, H. B. Peacock, Cecil H. Green, and Sigmund Hammer, have been of great service in advising the Editor on policy matters. Mr. W. T. Born, Jr. and his Reviews Committee are to be thanked for their work in preparing the reviews section of GEOPHYSICS. Mr. O. F. Ritzmann has continued his much appreciated coverage of geophysical patents through his fifteenth year of such service. The Editor is also appreciative of the helpful cooperation given him by President R. C. Dunlap, Jr. and the other members of the Executive Committee. Our society's business manager, Mr. Colin C. Campbell, has been of great assistance throughout the year in helping the Editor in every possible way.

The Editor wishes to express his appreciation to The Carter Oil Company management for permitting him to carry out his editorial assignment and for making available the necessary secretarial assistance so important to the carrying out of the assignment. Finally, this Editor is most grateful to the many referees of the papers published in GEOPHYSICS for their diligent and careful evaluation

TECHNICAL PAPERS BY CATEGORY

	1955					1956				
	Jan.	Apr.	July	Oct.	Total	Jan.	Apr.	July	Oct.	Total
Seismic Theory: Experimental Seismology	5	4	2	4	15	3	8	2	2	15
Seismic Field Techniques and Operations	1	2	1	—	4	—	2	3	3	8
Gravity Prospecting	1	1	—	1	3	2	—	1	2	5
Magnetic Prospecting	—	1	—	1	2	—	1	1	2	4
Electrical Prospecting	2	1	2	2	7	—	3	2	2	7
Mining Geophysics	—	—	1	1	2	—	1	—	—	1
Miscellaneous Technical	—	—	1	—	1	—	—	2	2	4
Case Histories	—	—	—	1	1	—	—	1	—	1
General Geophysical Prospecting	1	—	—	1	2	1	—	1	—	2
Instrumentation	1	—	1	—	2	—	—	—	1	1
TOTALS	11	9	8	11	39	6	15	13	14	48

of these papers although they remain necessarily anonymous, even in many cases, to the Editor himself.

The Editor has given considerable attention during the year to the future growth of our journal, GEOPHYSICS. Since the development of future techniques must flow from physics, the Editor has actively advocated that the Society of Exploration Geophysicists become a member society of the American Institute of Physics to the end that its influence may extend into the broader realms of physics and that in turn it may receive from the broad field of physics the necessary flow of men and ideas into geophysical prospecting.

Although the editorial work connected with producing and developing a scientific journal of the type represented by GEOPHYSICS requires a great deal of time and effort, it has its rewards through being able to see a steady growth and improvement in quality of the journal, to which the Editor has the opportunity and satisfaction of contributing. This is his reward.

NORMAN RICKER

ANNUAL REPORT OF THE STANDING COMMITTEE ON STUDENT MEMBERSHIP

This committee is composed of the following:

F. J. Agnich, Chairman
John T. Geer
John Hollister
J. Tuzo Wilson

It is the objective of this committee to attract into the geophysical profession as many technically trained individuals as possible. To accomplish this objective the committee has been engaged in three programs:

1. Increasing the number of student members through individual application and through assistance in the formulation of new affiliated student societies.
2. Conducting annual student essay contests in geophysics.
3. Administrating scholarships in geophysics.

The results of and recommendations for these programs are as follows:

1. *Student Membership Program*

Little has been done by this committee in fostering additions to our student membership list through the use of individual applications. A great deal more has been accomplished in the fostering of new student sections.

During the two years this committee has been active the following student societies have been formed and affiliated with the SEG:

Trans Pecos Student Section
Pennsylvania State University Geophysical Society
University of Utah Geophysical Society
Georgia Institute of Technology Geophysical Society

This brings to nine the number of student societies now affiliated with the SEG. The chairman of this committee has delivered addresses before three of these student groups during the past year.

It is recommended that the committee continue its active support of the various student societies. Most of the student societies experience difficulty in arranging for programs. Understandably the societies do not possess financial means to provide for transportation or expenses for someone to deliver a paper before them. However, addresses by members of industry are extremely important. It is a fact that in many cases students will pay great attention to advice and direction offered by someone from industry when they might not as readily accept the same from their own faculty. This committee therefore will endeavor to arrange for representatives from industry to deliver papers before the various student sections. This can often be accomplished at the time of a visit by some industry representative to their school for the purpose of recruiting. The various affiliated geophysical societies (not the student societies) will be contacted directly to see whether or not they will be able to help in this important project. The committee will also seek to do more in the way of soliciting individual student memberships by including applications in announcements of the student essay contest which are sent annually to a great many of the educational institutions in the United States and Canada.

2. *Student Essay Contest*

The two student essay contests which so far have been held have not been very successful and it appears the third one now in progress will show little improvement. There has been a great deal of interest but a lack of papers submitted. In the 1954 contest only two papers were submitted and in the 1955 contest only three. Part of the difficulty in securing papers rests in the timing of the National Meeting. In past years the National Meeting has fallen toward the end of the student year and since most of the participants are seniors, the problem of writing an essay at that time of the year imposes a great burden. The present timing of the National Meeting falls too soon after the start of the school year and it is difficult to keep in touch with the students for the purpose of keeping up their enthusiasm for the essay contest.

In view of the above it is recommended that the rule requiring the participants to be undergraduate students as of January 1 of the year of the contest be altered and that instead an additional year's leeway be granted. For instance, for the 1956 contest all participants must have been of undergraduate status as of January 1, 1956. It is recommended that the time be extended one full year. In other words, for the 1957 contest all participants who are undergraduates as of January 1, 1956, would be considered. Most students are not involved in the preparation of professional type papers until the latter part of their senior year. They are extremely busy during this period and most of them simply do not have the time to edit the paper, polish it up or otherwise prepare it to meet the standards which have been set by this committee. This new schedule would open to the contest the most fertile period of undergraduate endeavor insofar as producing papers is concerned. While it would include many students working on their master's degrees, it would also be, in effect, a com-

promise since it would eliminate those who have progressed very far toward their doctor's degrees. The latter point is of some significance because those who are well along the way toward a doctor's degree are sufficiently far enough along to participate in the SEG Best Paper Contest. In addition, it would eliminate that appreciable group of individuals who, after having secured considerable experience in industry, return at a later date for advanced schooling.

This committee respectfully requests the opinion of the Executive Committee on this recommendation.

3. Scholarships

The committee handled applications for two scholarships during 1956 and this marked the first time this activity has existed. There was no dearth of applications and the decision as to the recipients was not easy. The Mayhew Scholarship in Geophysics was awarded to R. F. McReynolds and the Griffin Scholarship was awarded to Ramil C. Wright. Mr. McReynolds will attend the Colorado School of Mines and Mr. Wright the Rice Institute.

Due to the lateness of word that these scholarships would be available it was necessary to set the deadline as of June 1. The committee believes this deadline is too late because considerable difficulty was found in securing a recipient of the Mayhew Scholarship who was enrolled at a university which offered a degree in geophysics as was required by the scholarship donor. It was at that time too late in the year in most cases for a recipient to become enrolled. Therefore, it was necessary to take the second individual recommended by the committee since the first one could not meet the above qualification. Therefore, it is the intention of the committee to set the deadline date as May 1 instead of June 1, provided the Executive Committee has no objection.

The chairman of the committee appointed a sub-committee headed by Mr. John T. Geer which also included Dr. John P. Woods and Mr. Cecil H. Green who made the recommendations as to the scholarship recipients.

It is apparent that the committee will be faced with a severe administrative load in the future since the number of these scholarships appears to be increasing rapidly and it is possible that next year we shall have some five or six such awards to be determined. If this does turn out to be the case, the volume of correspondence which will be necessary to check the qualifications of all the applicants will be overburdening for the committee under its present setup. The chairman proposes to discuss the matter in detail with Mr. Colin Campbell to see if some additional help can be secured from the Business Office. In addition, the Chairman recommends that in the future, where possible, the committee should be composed largely of people located in one section of the country or even better in one town. This is the only way in which rapid screening and processing of applications may be accomplished since the time consumed in sending the applications to other places would make it impossible to meet any kind of a deadline.

Mr. Colin Campbell brought to the attention of the chairman the possibility of taking advantage of the facilities of the National Merit Scholarship Corporation for administering the SEG scholarship activities. There has not been sufficient time to fully evaluate this possibility but it appears to be of considerable interest and it is recommended that this approach be investigated and a decision arrived at by the end of the year.

The chairman of this committee has found that the opportunity to work closely with students and with members of faculty has been an inspiring one and well worth the effort he has been able to put into the endeavor. However, in view of his recent appointment as General Chairman of the 1957 National SEG Meeting in Dallas, he regretfully suggests that the program of the committee could be better carried out by someone else not faced with so many demands on his time. If desirable, he will gladly continue as a member of the committee and will offer all help and suggestions he possibly can.

F. J. AGNICH

31 August, 1956

REPORT—1956

STANDING COMMITTEE—RADIO FACILITIES

R. D. Wyckoff—Chairman
W. M. Rust, Jr.—Vice Chairman & Chairman, Houston District
R. T. Wade—Chairman, Shreveport District
George Belt—Chairman, Ft. Worth District
E. M. Shook—Chairman, Dallas District
J. O. Parr—Chairman, San Antonio District
Daniel Silverman—Chairman, Tulsa District
Bart W. Sorge—Chairman, California District

No formal meetings of the Radio Facilities Committee were held during the 1955–1956 period since our agenda has remained cleared of matters requiring such action.

By the terms of original organizational agreements, our affiliation with the A.P.I. Central Committee on Radio Facilities and the National Petroleum Radio Frequency Coordinating Association involves participation in the activities and meetings of these organizations. The API Committee includes a Subcommittee on Geophysical Use of Radio and in the NPRFCA organization, geophysics is recognized as one of five phases of the petroleum industry involved and has equivalent representation. Thus SEG members participate in all discussions of radio matters that come before these bodies and those directly pertinent to geophysical operations receive conscientious consideration. Questions arising in the API and NPRFCA activities requiring the overall concensus of the geophysical industry are referred to the SEG Radio Facilities Committee.

During 1956 the FCC received requests from several geophysical operators for permission to operate on two frequencies. Since such dual-frequency authorizations had not previously been made the FCC referred the matter to NPRFCA to ascertain the attitude of the Petroleum Service regarding such operation. This matter was referred to and mail ballots received from the SEG District Subcommittees. As a result NPRFCA advised the FCC by letter that "the NPRFCA has studied this problem extensively and recommends that in special cases, upon representation of a need for two frequencies and agreement to make a serious effort to engineer a safe and adequate use of a single frequency as soon as possible use of two frequencies be permitted on an interim basis. In such a situation, only one frequency is to be used for voice communications."

The API Central Committee has requested revision of our 1951 Report entitled, "Radio Facilities in Exploration Geophysics." This revision to bring it up-to-date is under way and should be completed before the end of this year. With this exception, the docket of this Committee is cleared.

R. D. WYCKOFF—*Chairman*
W. M. RUST, JR.—*Vice Chairman*

REPORT OF ACTIVITIES OF THE MEMBERSHIP COMMITTEE OCTOBER 1955 TO OCTOBER 1956

The Membership Committee representing the Society of Exploration Geophysicists during the last fiscal year was

J. E. (Sam) McGee
Bart W. Sorge
H. M. Thralls, Chairman

The initial activities of the committee were patterned after those of the previous committee headed by Mr. Sorge. In his report of October 1955 Mr. Sorge listed as sources of new members the following:

1. Members of local sections who are not members of the national organization.
2. Co-workers or acquaintances of members.

3. Non-members attending national or regional meetings.
4. Students.

Using Mr. Sorge's outline as a base, form letters were mailed to:

a) Members of local sections who were not members of the national society urging them to apply for membership in the category for which they were qualified.
b) Members of the National Society who were not members of local sections urging them to join local sections.
c) Non-members who attended the national or regional conventions.
d) A selected list of delegates to the Nuclear Congress and Atomic Exposition held at Cleveland, Ohio.
e) Members delinquent in dues and dropped from the rolls on January 1, 1956, urging them to reinstate their membership.

Applications for membership from areas wherein active local sections are operating dominate the new member statistics. Letters to members of the national society who were not members of local sections received phenomenal acceptance and disclosed a pronounced interest by the average member in local section activities. A large number of members stationed in areas wherein no local section was active answered the form letter expressing their desire for affiliation with some local group.

New member statistics and the interest of members in local sections were referred to the Executive Committee and resulted in a directive from the Executive group to the Membership Committee to the effect that they should follow up the letters of interest regarding local sections and encourage the formation of new sections. This project was started in August 1956 and is incomplete. It will be transferred to the new committee.

The work of the membership committee was reduced to a mechanical task by the high level of cooperation from members, the local sections, the Executive Committee, and the Business Office of the S.E.G. To all of these the Membership Committee wish to express their sincere appreciation.

H. M. THRALLS

Tulsa, Oklahoma
August 28, 1956

SUMMARY OF CHANGES IN MEMBERSHIP COUNT

FOR FISCAL YEAR (JULY 1, 1955 TO JUNE 30, 1956)

	Hon.	*Life*	*Active*	*Associate*	*Student*	*Total*
Balance Brought Forward June 30, 1955	5	2	2,808	1,706	243	4,764
Changes for Fiscal Year:						
Elected			184	254	53	491
Transferred	3		105	(94)	(14)	—
Resignation			(10)	(25)	(6)	(41)
Deceased	(2)		(13)	(2)		(17)
Suspended			(34)	(92)	(12)	(138)
Reinstatement:						
Dropped Members			7	7		14
Suspended Members			11	13	1	25
JUNE 30, 1956 BALANCE	6	2	3,058	1,767	265	5,098

List of Deceased Members

*Ervin C. Brede			1	
Karl E. Lewis		1		
L. I. Brockway		1		
E. L. Caster		1		
F. L. Bishop		1		
J. B. H. Henderson		1		
Frank M. Cowell, Jr.		1		
William E. Pugh		1		
L. F. Athy		1		
James A. Moore		1		
##L. Mintrop	1			
##Rev. Jas. B. Macelwane, S. J.	1			
*Jerry Nelson			1	
C. A. Heiland		1		
Edwin Jones Kieth		1		
Morris M. Slotnick		1		
J. W. Richardson		1		
TOTALS	2	13	2	17

REPORT OF THE STANDING COMMITTEE ON HONORS AND AWARDS

During the year 1955–1956 the membership of the Standing Committee on Honors and Awards was:

Andrew Gilmour	(56)
George E. Wagoner	(57)
Sigmund Hammer	(58)
Curtis H. Johnson	(59)
Roy L. Lay	(60)

The plan of voting for the best paper award was that instituted by Norman Ricker two years ago. The outstanding choice among members of the Committee was the paper on "The synthesis of Seismograms from Well Log Data" by R. A. Peterson, W. R. Fillipone and F. B. Coker published in the July 1955 issue of GEOPHYSICS.

The Committee voted to award an honorary membership to Dr. L. L. Nettleton at the New Orleans Meeting.

ANDREW GILMOUR

REPORT OF THE STANDING COMMITTEE ON PUBLICATIONS

The members of this committee are Cecil H. Green, Sigmund Hammer, L. L. Nettleton, H. B. Peacock, and J. P. Woods. The committee makes recommendations to the Society concerning the various Society publications.

During the past year, these recommendations have been made:

(1) That supplements to the Index of Wells Shot for Velocity continue to be published in GEOPHYSICS and that re-prints be made available.

(2) That the SEG join the EAEG in the publication of a mining case histories volume.

(3) That the Society consider various special publications, the first of these to be Computer's Manual. This manual would contain re-prints of appropriate papers in GEOPHYSICS plus

Honorary Member
* Associate Member
All others are Active Members.

necessary new papers dealing with seismic computations. This project is now in the hands of a sub-committee with Dr. M. B. Dobrin as chairman.

(4) That the Society re-publish the volume EARLY GEOPHYSICAL PAPERS provided that sufficient advance orders are received. To date some 500 copies of this volume are on order.

The committee has also discussed several matters of publication policy referred to it by the editor of GEOPHYSICS.

J. P. WOODS

REPORT OF THE STANDING COMMITTEE ON REVIEWS

The present Reviews Committee was appointed by the Editor in October of 1955 to serve for a term of two years. We were to prepare reviews for GEOPHYSICS beginning with the January, 1956, issue. Since the copy for that issue was due within a few weeks after our appointment, we called upon Dr. Nelson C. Steenland, Chairman of the outgoing Committee for help. He responded promptly and effectively, and his Committee contributed most of the reviews published in the January, 1956, issue. Our Committee is most grateful for this assistance and wishes here to thank Dr. Steenland and his committee members for their very great help in our time of need.

During the year 1956 a total of twenty-seven reviews were published. Of these, nine were reviews of books or brochures, the others concerned articles in technical journals. By subject matter, eight of the reviews dealt with geological material, thought to be of interest to geophysicists. Of the geophysical items reviewed, six concerned seismic subjects, two magnetic, two electrical, one gravity and one radioactivity. The remainder were miscellaneous.

Our Committee suffered a grievous loss during the year through the death of Dr. M. M. Slotnick, a long-time member of this Society, and a valued member of our Committee. Dr. Slotnick had been a member of previous Reviews Committees and his advice, as well as his contributions will be greatly missed.

To replace Dr. Slotnick, the Editor has appointed Mr. E. V. McCollum of E. V. McCollum and Co., Tulsa, Oklahoma.

Many of the reviews published in GEOPHYSICS are written by reviewers not members of our Committee. Such contributions are welcomed and are gratefully received. Your Committee also welcomes suggestions from members regarding items which they would like to have reviewed.

In closing, your Chairman wishes to extend his thanks to our Business Manager, Mr. Colin Campbell, who supplies us with current publications, and who has called our attention to much material which might otherwise be overlooked.

W. T. BORN

REPORT OF STANDING COMMITTEE ON PUBLICITY

The Standing Committee on Publicity for the year 1955 to 1956 was composed of 17 members, one from each of the local Sections, and the Chairman, as follows:

G. A. Burton	R. B. Harwell	H. G. McCleary
John Byers	L. J. Larguier	W. R. O'Brien
G. M. Conklin	Russell L. Long	Lorne H. Reed
John G. Cooke, Jr.	W. A. Meszaros	K. Watson
H. V. Crowder	L. K. Morris	Thomas S. West
Lynn D. Ervin	John C. McCaslin	

No major project was in progress during the year.

An important part of the activities of this Committee was carried out through the efforts of the local Sections by direct contact with the local press and the public. These are principally as follows:

1. Maintaining close contact with the local press and securing suitable coverage for publicity releases, rewriting and adapting them to local needs in some instances.
2. Publicizing the activities of the local Sections through newspapers and other media.
3. Addressing civic, student, and other groups, often jointly with local geological societies. A limited number of *Careers in Exploration Geophysics* were distributed.

4. Securing excellent publicity for the forthcoming national meeting in New Orleans and for regional meetings and their speakers.

Matters receiving the attention of this Committee during the year are principally as follows:

1. A more widespread distribution of news releases was secured by expanding the mailing list to include all significant newspapers in the areas of the local societies and some of the larger newspapers in other areas.
2. The new *Scholarship Program* and the *Annual Student Essay Contest* were given excellent publicity on both local and national levels.
3. Adequate publicity is planned for the *Report on Geophysical Acitvity in 1955*, and the *Honorary Membership Awards for 1956*.
4. Certain thoughts were expressed by the Chairman aimed toward consideration of employing professional counsel for more effective nationwide publicity particularly through visual channels.
5. The thought has been expressed by many of the members of this Committee to resume contacts with high school students and distribute *Careers in Exploration Geophysics* which action is strongly recommended through the coming years as a regular function of this Committee.

The unfailing and willing cooperation and assistance received from Colin C. Campbell, Business Manager, is gratefully acknowledged.

P. E. NARVARTE

REPORT OF ACTIVITIES OF THE PUBLIC RELATIONS COMMITTEE

The present membership of the Public Relations Committee is as follows:

Roy Bennett
Eugene Frowe
F. O. Mortlock
Ralph B. Ross
Bart W. Sorge, Chairman

The Committee, upon being formed in January, 1956, considered the various lines of endeavor that might be followed to improve public relations for the Society and the geophysical industry. It was decided to concentrate our effort on endeavors which would attract more technically trained people into the geophysical business. There are innumerable ways in which these results can be achieved. So far, the primary purpose of our activity has been to call attention to geophysics as an interesting and worthwhile means of livelihood to high school and college students. To achieve the desired results, the following activities have been undertaken:

Boy Scout Merit Badge in Geophysics:

The national headquarters of the Boy Scouts of America were contacted with the suggestion that they establish a Merit Badge in geophysics similar to the one that exists for geology. At the same time, communications were entered into with the Boy Scout Merit Badge Committee of the AAPG and AGI. As a result of these communications, it has been decided that we would be able to accomplish the greatest good by cooperating with the AGI and the AAPG Merit Badge Committees in establishing several Merit Badges related to the earth sciences. This work is not complete and will be prosecuted further.

Notices of Job Opportunities:

In April, 1956, 300 geophysical operators, both oil companies and contractors, were contacted by mail and notified that the Public Relations Committee planned to send a bulletin of employment opportunities, both for regular and summer work, to science departments of a large number of universities in the United States and Canada. As a result of these letters, the Committee received notices

from fifty organizations indicating a desire to hire permanent employees and notices from twenty-eight organizations to hire college students for summer employment.

The names of these companies were incorporated into two lists, one for those expressing a need for permanent employees, and one for summer employees. These lists, together with an accompanying letter, were then mailed by the Tulsa business office, through a mailing service, to over four-thousand university science departments in the United States and Canada.

The response to this effort was overwhelming, particularly in regard to students seeking summer employment. It is planned to duplicate this effort next year but at an earlier date since many companies do the majority of their hiring earlier than the end of the school semester.

Solicitation of Geophysical Scholarships:

Due to the great interest created by the geophysical scholarships established by the Mayhew and Griffin organizations of Dallas, Texas, and the Seismic Service Supply Company of Calgary, Alberta, Canada, it was decided to broaden this activity and contact other organizations in the United States and Canada in regard to establishing additional geophysical scholarships. This will create a further interest in geophysics on the part of univeristy students. This effort is presently being carried out in the United States by our Committee and in Canada by the Canadian Geophysical Society. It is hoped by the time of the annual meeting that progress can be reported.

Simple Geophysical Projects Suitable for High School Students:

The Committee has received several requests for simple work projects suitable for high school students that would demonstrate geophysical principles. Our Committee has considered many suggestions, but to date has not decided on project material due to the difficulty encountered in creating a project simple enough and yet informative. Efforts along this line will be continued.

Education of High School Science Teachers in Regard to Geophysics:

Suggestions have come to the Committee during the year from several sources regarding the desirability of making available to high school science teachers material that would acquaint them with the science of geophysics. Ways and means of accomplishing this have been explored but no definite steps have been taken as yet.

A worth-while project exists at the University of Alberta where an oil-company sponsored summer course is furnished free to high school physics teachers to acquaint them with current research in physics.

This project will be discussed by the Committee at the meeting in New Orleans and will be prosecuted during the coming year.

Articles or Stories in Popular Magazines:

During the last twenty years articles or fiction stories have occasionally appeared in popular magazines that have dealt with geophysics. It is deemed very desirable to encourage additional articles in the future. Some writers and magazines have been contacted. Due to the nature of this effort, more time will be needed to accomplish the desired results.

Revision of CAREERS IN EXPLORATION GEOPHYSICS:

It is planned to make a few revisions in the excellent brochure, CAREERS IN EXPLORATION GEOPHYSICS, published by our predecessors. Some of these changes are necessary to keep the brochure up to date, particularly pertaining to salaries. This work has not been carried to completion as yet due to the fact that about 20,000 copies of the brochure are still on hand in Tulsa. As soon as this supply is exhausted the Committee will finalize the revisions to permit additional copies of this very useful brochure to be printed.

SEG Cooperation in the International Geophysical Year:

At the suggestion of Past President Paul Lyons, and with the approval of the SEG Executive Committee, the Public Relations Committee contacted the U. S. Chairman of the International

Geophysical Year, Dr. Joseph Kaplan, and offered the assistance of the Society in carrying out a project of measuring the reflection time of reflections of the mohorovicic layer on a world-wide basis. The U. S. International Geophysical Year Committee gladly accepted our offer, and since then communications have been carried on with members of the International Geophysical Year organization in regard to some of the details of the proposed project.

There are a number of problems that need to be solved in connection with this project, and it is the recommendation of the Public Relations Committee that the Society appoint a special committee to vigorously prosecute this project so that all plans can be ready and associated problems solved at the beginning of the International Geophysical Year in July, 1957.

The Canadian Geophysical Society has offered to be the liaison between the Canadian Committee for the International Geophysical Year and the oil industry. They have received favorable response from Dr. Beals of the IGY, and details are being worked out.

In addition to the above activities, a great number of requests for information have been received as a result of the mailing of the employment bulletins. The information requested has been furnished as much as possible, and we wish to acknowledge the valuable assistance that the SEG business office has rendered in this task.

All of the above projects have been initiated and are being continued with the idea of creating an interest in geophysics among high school and college students and of spreading information about geophysics among those who are in a position to educate and influence science students.

The Committee feels strongly that only through the successful dissemination of information about geophysics can our industry hope to alleviate the present shortage of qualified and technically trained personnel. Towards this end the Committee will continue its endeavor to achieve the desired results.

It has been a privilege and a pleasure to serve the Society during this past year.

BART W. SORGE

REPORT OF THE STANDING COMMITTEE ON GEOPHYSICAL ACTIVITY

Since the last National Meeting of the Society at Denver, Colorado in October, 1955 there have been several changes in the membership of the Standing Committee on Geophysical Activity of the Society of Exploration Geophysicists. After many years of valuable service as chairman of the committee, Dr. Sigmund Hammer resigned. Homer G. Patrick, a new member, assumed the chairmanship and others were added as replacements for those who resigned or as new members of the committee (see listing of members below).

The first task of the committee this year was to prepare the full-year report, "Geophysical Activity in 1955." After much delay in assembling the statistical data, the report was completed in August. Unfortunately, at this late date, it was not possible to publish the report in GEOPHYSICS.

The report "Geophysical Activity in 1956–Interim Report to Midyear" is scheduled for oral presentation at the SEG convention in New Orleans, Louisiana on October 29.

The present members of the committee and their assigned jurisdictions are as follows:

Kenneth L. Cook, University of Utah—Mining Geophysics
R. J. Copeland, Canadian Gulf Oil Company—Canada
Santos Figueroa Huerta, Petroleos Mexicanos—Mexico
W. W. Hardy, Socony Mobil Oil Company, Inc.—Europe, Africa, Near East, Far East
Herbert Hoover, Jr., Member at large
C. N. Hurry, The Carter Oil Company—Mid-Continent, Rocky Mountain and Eastern U.S.A.
Kumiji Iida, Nagoya University—Japan and Formosa
C. C. Lister, United Geophysical Corporation—South America, Central America, West Indies
Homer G. Patrick, Humble Oil & Refining Company—Alaska, Pacific Coast, Southern and Southwestern U.S.A.

Interest in the reports continues at a high level. The statistical information on geophysical activity is useful not only to those engaged in geophysics, but also to suppliers, service companies,

governmental agencies and others who are interested in the petroleum and mining industries.

The members of the committee feel that Dr. Sigmund Hammer is deserving of special commendation for the long, faithful and untiring service he devoted to the work of the Committee.

HOMER G. PATRICK

August 29, 1956

REPORT OF THE STANDING COMMITTEE ON SAFETY

The Standing Committee on Safety is composed of the following members:

G. M. Kintz	Elmer Johnson
E. L. Wells	W. H. Hawkes
R. N. Brantley	B. W. Sorge
P. M. Hanahen	R. C. Henderson

W. H. Newton

The Committee's basic policy of encouraging and aiding geophysical operators in the establishment and operation of loss-control and accident-prevention programs was continued during the period covered by this report.

Activities of the Committee, continued from previous years, included:

1. Operation of the Geophysical Accident Information Exchange on an anonymous, voluntary basis as a means of distributing information concerning the types of mishaps which are costing the industry so much time and money.
2. Collection and publication of statistical data concerning the occurrence of accidents on geophysical parties. The reporting period has been changed from monthly to semi-annually.
3. Publication of "Geophysical Safety Tips" (bi-monthly) and "Doodlebuggin' the Safe Way" (quarterly).
4. Making available visual aids (35 mm colorslides with accompanying printed lecture notes) for geophysical safety training.
5. Providing speakers and films for local, regional, and national meeting.
6. Making available for sale posters stressing geophysical safety.
7. Providing safety consulting service to geophysical operators who want to initiate loss-control programs.

New activities of the Committee included:

1. Announcement to the industry of a new Safetygraph prepared specifically for geophysical company employees. Since there was no indication of favorable response to this announcement, preparation of the Safetygraph was suspended.
2. Initiation of a driver training manual specifically designed for employees of geophysical operators.
3. Holding a safety poster contest open to all SEG members and employees of companies engaged in oil exploration work.
4. Initiating a program designed to persuade manufacturers and suppliers to the industry to incorporate safety and job training into their advertising and public relations programs. Two firms have done so, and a third has indicated that a safety section would appear in the next issue of their operating manual.

WILLIAM H. NEWTON

REPORT OF THE CASE HISTORIES COMMITTEE

As Chairman of the Case Histories Committee, I wish to report that Case Histories Volume II was sent to the publishers during the latter part of May or early June and the finished volume was in the hands of the subscribers early in July of this year.

With regard to the continuing of the Case Histories volume series, no actual steps have been

taken to obtain papers for Volume III, but it is my intention to begin my organization for this purpose in a short while and will actively solicit papers for the future Case Histories publication.

DAVE P. CARLTON

REPORT OF THE CONSTITUTION AND BYLAWS COMMITTEE

The routine work of the Constitution and Bylaws Committee the past year included approval of the proposed Constitution and Bylaws of the Southwest Louisiana Geophysical Society and the Georgia Tech Student Section of SEG and amendments of the Constitution and Bylaws of the Geophysical Society of Oklahoma City.

The major work of the Committee has been a thorough study of the Constitution and Bylaws. The objects of this study were to apply to the Constitution and Bylaws the lessons taught by experience during the past eight years, to streamline the Constitution and Bylaws and to provide for a new class of Members.

When the Constitution was last amended in 1948, one of the major objectives was to provide for Local Sections. The success of this effort is now evident. However, the details of the actual development were not all exactly as anticipated. For example, no Local Section has needed regular financial aid from the National Society. Also, it has not proved desirable to assign specific geographical territory to the Local Sections. The proposed amendments take these lessons into account.

The Council of SEG, created by the amendments of 1948, has proved to be as important as anticipated. However, the method proposed for providing representation on the Council for members of SEG who are not members of Local Sections has proved unworkable. These amendments provide a more practical method and also provide a uniform method of electing Local Representatives.

The Constitution and Bylaws have been streamlined by relegating to a Procedures Manual much of the details of operations, such as Committee structure, retaining in the Constitution and Bylaws only items of general concern.

These amendments provide for a new class of Member, the Sustaining Member, who is an individual or company that wishes to promote SEG's objectives by payment of annual dues of $100 or more. Finally, these amendments recognize the effects of inflation by increasing the annual dues of all classes of members.

These amendments will be submitted for discussion by the Council at the Annual Meeting in New Orleans and, if approved, to the membership in a mail ballot.

W. M. RUST, JR., *Chairman*

REPORT OF THE SPECIAL COMMITTEE ON THE AMERICAN INSTITUTE OF PHYSICS

Following the signing of the petition for membership in the American Institute of Physics by the Executive Committee of the Society of Exploration Geophysicists on March 7, 1956 in Fort Worth, Texas, the committee on AIP was appointed by President Dunlap to prosecute this petition and to carry on any negotiations with AIP as might be necessary in consummating this petition for membership. The membership of the committee is as follows:

Norman Ricker, Chairman	L. Y. Faust
C. B. Bazzoni	Sigmund Hammer
D. H. Clewell	D. S. Hughes
Maurice Ewing	L. B. Slichter

Upon receipt of our petition by the secretary of the AIP the executive committee of the AIP recommended our petition to the Governing Board and the Governing Board unanimously passed favorably upon our petition and set SEG up in candidacy for membership. Our petition must now be passed upon by the governing groups of the separate member societies. A favorable action by four of the five member societies is sufficient to elect SEG to membership. Unofficial information informs us that the processing of our petition is going very nicely but we shall not have a final decision

until probably next January. If SEG is accepted for membership in AIP we shall become a member society upon payment of our dues which will be ten per cent of our dues collected. This will amount to less than one dollar per member per year. Each member of SEG will then receive regularly the monthly journal "Physics Today" which contains all the news of physics and through this journal news of SEG activities will reach into the broader fields of physics.

NORMAN RICKER, *Chairman*

1956 REPORT OF THE RESEARCH COMMITTEE

At the annual meeting of SEG in Denver last year the Research Committee, which at that time had been in existence for only one year, was given the status of a Standing Committee. The members of the committee are pleased with this permanent recognition that has been awarded to research by SEG.

1. Now that the committee is a standing committee, it has been recommended that Research Committee members be appointed for a term of three years and that the appointments be staggered so that one-third of the membership retires each year. It is also recommended that, in addition to the appointment of a chairman, a vice-chairman and secretary be appointed who would succeed the chairman and vice-chairman, respectively, on a yearly basis. Our Committee has met twice in the past year and hopes to continue the practice of meeting at times and places coincident with the annual meetings of SEG and AAPG.

2. In last year's report mention was made of the activities of the American Petroleum Institute in setting up a program of research in Geophysics. This program is now underway. Five grants-in-aid have been awarded to:

a. Francis Birch, Harvard University
b. Maurice Ewing, Columbia University
c. Darrell Hughes, The University of Texas
d. Beno Gutenberg and Frank Press, California Institute of Technology
e. Hewitt Dix, California Institute of Technology

The API has appointed a Geophysical Research Committee to administer these grants-in-aid under the chairmanship of Dan Silverman. Other members of the SEG Research Committee, who are also members of the API Committee, are Messrs. H. F. Dunlap, J. M. Crawford, T. J. O'Donnell, D. H. Clewell, J. E. White, and B. D. Lee.

Our SEG Research Committee has cooperated with the API in the initiation of the program. The API expenditures during the coming year on this program will amount to approximately $32,500.

3. Ray Peterson's committee on University Symposia has arranged for Rice Institute to sponsor a symposium on geophysics in Houston next spring. The purposes of the symposium are three-fold:

(1) To bring university and industrial research workers together in fields of common interest.
(2) To stimulate fundamental research in the universities in fields basic to exploration geophysics.
(3) To produce a major inventory or summary of the present state of knowledge in all areas of geophysics.

Dr. Noyes Smith has agreed to serve as chairman of an Advisory Committee to work with Rice Institute in the formulation of the program. Other members of the advisory committee are listed at the end of this report. It has also been recommended to the SEG Council that the proceedings of the symposium be published by the SEG so that they will become available to the SEG membership and to academic institutions.

4. L. L. Nettleton's committee on Thesis Subjects has been active in listing subjects that could be recommended to graduate students. The committee has answered a number of specific inquiries that have been directed to it by graduate students and university staff members.

5. Our committee deeply regrets that it must report the death of one of its members, Father J. B. Macelwane.

6. The Research Committee is again sponsoring a geophysical research review paper for presentation at the annual meeting in New Orleans. Dr. Milton B. Dobrin, former editor of GEOPHYSICS, has primary responsibility for the organization of this paper as he did last year. Dr. Henry F. Dunlap, a member of the Research Committee, is collaborating with Dr. Dobrin on the paper. This year, major emphasis will be given to a review of geophysical research that is active in academic institutions.

The present membership of the Research Committee and its sub-committees is as follows:

D. H. Clewell, Magnolia Petroleum Company, Dallas, Texas—Chairman
H. F. Dunlap, Atlantic Refining Company, Dallas, Texas—Secretary
C. H. Dix, California Institute of Technology, Pasadena, California
R. A. Peterson, United Geophysical Company, Altadena, California
P. S. Williams, Carter Oil Company, Tulsa, Oklahoma
C. H. Green, Geophysical Service Incorporated, Dallas, Texas
W. T. Born, Geophysical Research Corporation, Tulsa, Oklahoma
Maurice Ewing, Lamont Geological Observatory, Columbia University, N. Y.
J. E. Hawkins, Seismograph Service Corporation, Tulsa, Oklahoma
T. J. O'Donnell, Gulf Research & Development Company, Pittsburgh, Pa.
L. L. Nettleton, Gravity Meter Exploration Company, Houston, Texas
B. D. Lee, the Texas Company, Bellaire, Texas
J. M. Crawford, Continental Oil Company, Ponca City, Oklahoma
Daniel Silverman, Stanolind Oil & Gas Company, Tulsa, Oklahoma
J. E. White, Ohio Oil Company, Denver, Colorado

Sub-Committee on University Symposia

Ray Peterson, Chairman
C. H. Dix
N. A. Riley

Sub-Committee on Thesis Subjects

L. L. Nettleton, Chairman
C. H. Green
B. D. Lee

Advisory Committee on Rice Institute Symposium

Noyes D. Smith, Jr.—Chairman,
(Shell Development Company—Houston)
R. A. Peterson
C. H. Dix
N. A. Riley,
(California Research Corporation
La Habra, California)
L. L. Nettleton
B. D. Lee

D. H. CLEWELL, *Chairman*

REPORT OF THE SPECIAL COMMITTEE ON THE INDEX OF WELLS SHOT FOR VELOCITY

The fourth supplement to the "Index of Wells Shot for Velocity" was published in the January 1956 issue of GEOPHYSICS. It is hoped that the fifth supplement will be compiled and ready for publication in the January 1957 issue.

The Committee wishes to thank the many oil companies, seismograph contractors, and individuals for their splendid cooperation in helping to obtain velocity information for the fourth supplement. We have again mailed some one-hundred letters soliciting information for the fifth supplement and we are pleased to report that the response to date has been excellent.

The forthcoming fifth supplement will show surveys not heretofore reported, most of which will be those shot in 1955 and 1956. Also, corrections and additional information on previously listed surveys will be included.

V. U. GAITHER, *Chairman*

REPORT OF THE COMMITTEE ON STANDARDIZATION OF MAGNETIC RECORDING

During the past year the Main Committee on Standardization of Magnetic Recording has held one meeting. This was at Denver, Colorado, on October 3, 1955. At that time the work of the two Subcommittees concerned with specific aspects of Standardization was reported on and recommendations were made regarding future activities of these Subcommittees.

The Subcommittee on Information on Magnetic Recorder Characteristics has continued work on assembling information on the characteristics of commercial recorders and on studying aspects which might be standardized. Mr. C. B. Scott has resigned as Chairman of the Committee and Mr. Sidney Kaufman has accepted the Chairmanship. Continuing the work of Mr. Scott, Mr. Kaufman's Subcommittee has completed a report which gives a comprehensive summary of the characteristics of eleven recorders now available for purchase. The specifications given include, among other items, the physical dimensions of the transport system, the speed and recording time, the type of modulation, the number, width and spacing of recording tracks, the signal-to-noise ratio and the amount of harmonic distortion. These specifications are those given by the manufacturer and no attempt has been made to check them by independent measurement. Also included is a brief description of the operations which can be done with each recorder. The report points out that "The various systems differ in basic design features to such a degree that it is difficult to anticipate the achievement of any large scale standardization."

The Subcommittee on Definitions and Measurements Procedures has continued its work with Mr. L. W. Erath as Chairman following the resignation of Mr. W. E. N. Doty. A report has been prepared recommending standardized terminology for specifying recorder characteristics and standardized measuring procedures for determining these characteristics. This has been a most difficult problem and the present recommendations are considered to be the best that can be developed at the present time. It is anticipated that as progress is made in recorder development, changes in these recommendations may prove desirable.

These two Subcommittees have worked hard, have held numerous meetings, and have done an excellent job on a very difficult problem. An important benefit, which although real is not readily apparent, is the opportunity that the Committee meetings have afforded for members of the various manufacturers to exchange ideas and suggestions. If this means of communication can be maintained in the future, it should be a material help in making progress toward standardization.

The reports of the two Subcommittees are being sent to the members of the Main Committee for review and they will then be submitted for publication in GEOPHYSICS as the best means of making them available to the members of the society.

R. R. THOMPSON, *Chairman*

August 17, 1956

REPORT OF THE ACTIVITIES OF THE BUSINESS OFFICE COMMITTEE

The Business Office Committee was composed of the following members:

Craig Ferris
E. M. McNatt
H. M. Thralls, Chairman

Excellent work by special business office committees under the direction of Karl Dyk and Stefan Von Croy, the close collaboration between recent Secretary-Treasurers and the business office, and the excellent accounting advice from the present auditors has eliminated most of the need for the Business Office Committee as a directive body.

The prime function of the Business Office Committee under present conditions is that of an advisory group to the Business Manager on everyday business problems. The Committee represents a safeguard in the absence of a resident executive body and provides the Business Manager a source of council for some of his perplexing problems.

Two formal sessions were held by the Business Office Committee. Numerous telephone and personal contacts were made by the Business Manager with members of the committee as conditions required.

The excess of revenue over expenditures of $6,030.49, or profit for the fiscal year of 1955–1956, reflects adequate management of society affairs at present revenue levels. Forward steps made by council action in October of 1955 and by the Executive Committee of the present fiscal year should provide a cushion of at least $7,500 for the fiscal year of 1956–1957 and an adequate profit margin of $10,000 or more by fiscal year 1957–1958. The above statement is intended to take ordinary inflationary trends into account.

The Business Office Committee wishes to commend the Executive Group for their recommendation to the council that a new class of membership, the "Sustaining Member," be created. Should the inflationary spiral overtake the more or less fixed income of the SEG, or should the SEG be confronted suddenly by a large and unexpected loss such as a deficit on a national convention, the "Sustaining Membership" could provide a legitimate vehicle for increased income that heretofore has not been in existence. Further, the Business Office Committee urgently urges the Council to take favorable action in their 1956 meeting on this recommendation.

H. M. THRALLS, *Chairman*

Tulsa, Oklahoma
August 28, 1956

REPORT OF THE STANDING COMMITTEE ON DISTINGUISHED LECTURES

During the year 1955–1956 the Standing Committee on Distinguished Lectures consisted of:

W. B. Agocs
F. F. Campbell
Peter Dehlinger, Chairman
M. E. Denson, Jr.
John L. Ferguson
R. A. Peterson

The customary two SEG Distinguished Lecture tours were made during the year: The fall lecturer was sponsored by the SEG alone and the spring lecturer jointly by the SEG and AAPG.

The 1955 fall lecturer was Mr. Victor Vacquier, professor of geophysics at the New Mexico Institute of Mining and Technology. The lecture was entitled "Geophysical Prospecting by Induced Electrical Polarization." It summarized some of the recent research of Mr. Vacquier and his coworkers at New Mexico Mines on using induced polarization techniques to locate ground water. Both laboratory and field procedures were described and the effect shown of fresh water on the polarization of a decay of potential when an interrupted direct current is introduced into the ground.

Mr. Vacquier's tour was made in January, 1956, and included thirteen talks to the following SEG Member Sections and Societies:

Pacific Coast Section (Southern and Northern Districts)
University of Utah Geophysical Society
Montana Geophysical Society
Casper Geophysical Society
Denver Geophysical Society
Geophysical Society of Tulsa
Geophysical Society of Oklahoma City
Dallas Geophysical Society
Southeastern Geophysical Society
SEG Houston Section
Geophysical Society of South Texas
Permian Basin Geophysical Society

Mr. Vacquier's talk was timely, stimulating, and was well received. The expense of the lecture to the SEG was $594.24. Member Sections were billed the customary amounts as follows:

Membership of Section	*Charge*
50 or less	$ 1.00 per member
51–100	$ 50.00
101–200	$100.00
201–300	$125.00
301 or more	$150.00

The income from this tour was $975.00, resulting in a net gain of $380.76 to the Society.

The spring lecturer, sponsored jointly, was Mr. James Affleck, geophysicist with the Gulf Research and Development Company. The lecture was entitled, "Geologic Interpretation of Aeromagnetic Surveys." It presented an excellent summary of the geologic factors that affect aeromagnetic data, especially the relative thickness of sedimentary layers in a structural basin. These technqiues were drawn from Mr. Affleck's long experience with magnetic surveys and the illustrations were kindly released by the Gulf Research and Development Company.

Mr. Affleck's tour was made in May, 1956. It included sixteen talks. One was to an SEG Section, ten were to joint SEG and AAPG Sections, and five to AAPG Sections. The following SEG Sections participated in the tour:

Houston Section
Pacific Coast (Southern and Northern Districts)
Geophysical Society of Tulsa
Permian Basin Geophysical Society
Jackson Geophysical Society
Dallas Geophysical Society
Fort Worth Geophysical Society
Dakota Geophysical Society
Casper Geophysical Society
Canadian Society of Exploration Geophysicists

The charges to SEG for its share of the lecture cost was $455.00. The Member Sections were billed as follows: The Houston Section $75.00 (they were not addressed jointly); the other ten joint talks cost SEG $380.00, each participating Member being billed for $38.00.

Mr. Vacquier made the 17th lecture series to the SEG sections, and Mr. Affleck the 18th. The 19th lecture series for the fall of 1956 is currently being arranged.

The Committee wishes to extend its thanks to Mr. E. Scott, Chairman of the AAPG Distinguished Lecture Committee, for so ably scheduling and handling Mr. Affleck's tour.

PETER DEHLINGER, *Chairman*

REPORT OF DIRECTORS AMERICAN GEOLOGICAL INSTITUTE

The SEG has continued its active support of the American Geological Institute during the past year. The Institute has continued to advance during the year in achieving the objectives set for it as a coordinating organization for member societies of the earth sciences.

The appointed SEG representatives on the AGI Board of Directors are:

Roy L. Lay—term expires Fall 1956
Paul L. Lyons—term expires Fall 1957

A new director must be appointed to take office at the Annual Meeting of AGI this Fall. It is suggested that outgoing president Dunlap be considered for appointment to this position, in line with the precedent established.

The AGI Board of Directors met April 25, 1956 at Chicago, at which meeting Mr. Lyons was

present. At that meeting, Mr. Robert C. Stephenson, the new Executive Director of AGI, was introduced by President M. M. Leighton.

At the meeting, several important considerations were dealt with. These were as follows:

1. The present method of financing (i.e. voluntary contributions of several member societies) is unsuitable and inadequate.
2. Funds are lacking for important projects, such as stimulating interest in the earth sciences in the high schools.

As a result of the discussions, board members have voted, by written ballot, on proposals to have the member societies accept collective responsibility for the basic cost of the AGI organization, estimated at $25,000 for the fiscal year 1956–1957. The SEG directors favored such a proposal. The directors also favored proposals to seek $100 sustaining memberships, to recruit industrial associates, and to seek smaller individual contributions through GEOTIMES, the newsletter of AGI.

The directors voted to change the name and format of the old *Newsletter* to GEOTIMES, and the first issues have been mailed out. The publication has more than $5,000 in advertising commitments assured to date, and the magazine is expected to be self sustaining in 3–5 years.

The AGI ended its fiscal year without an anticipated deficit due to a grant of $13,000 by the National Science Foundation. A grant of $20,200 has been requested for 1956–1957.

On August 1, AGI moved into new offices in the new AAAS Building in Washington, and the AGI is indebted to the NAS-NRC for providing the much needed adequate space.

A resolution was passed approving (subject to acceptance by the individual societies) the Geochemical Society into AGI. Attached to this report is a formal request for appropriate action by SEG.

The AGI Glossary will be published this Fall; SEG participated in its compilation.

A directory of Geologists and Geophysicists is planned for publication in 1957 as a by-product of the Earth Science Register project supported by the National Science Foundation.

For additional plans and accomplishments of the AGI, refer to the issues of GEOTIMES.

A budget of $58,740 was presented for 1956–1957. It is the considered opinion of the SEG directors that this represents too ambitious a program at this time, in view of the difficulties in acquiring income for the AGI, and that the growth of the budget and the organization should follow, not lead, the very splendid efforts that are being made to obtain income.

Director Roy L. Lay served on the Ad Hoc Committee which participated in the Nuclear Science Program held in Cleveland in the Fall of 1956. There were enough papers for four sessions on geology and geophysics. Plans were laid for another such meeting early in 1957.

Recommendations:

As representatives of SEG in the Council of AGI, we are firmly convinced that AGI is performing and will continue to perform a useful service to the membership of SEG. Therefore, we recommend the following actions:

1. That SEG continue to support AGI financially, and that the Council of SEG should consider increasing the Society's contribution to the range $2,000–$3,000 for the year ahead.
2. That SEG cooperate, as in the past, in formulating and executing the plans and objectives of the AGI.

PAUL L. LYONS
ROY L. LAY

REPORT OF THE REPRESENTATIVE OF SEG ON THE DIVISION OF EARTH SCIENCES NATIONAL ACADEMY-NATIONAL RESEARCH COUNCIL

The Division of Earth Sciences is at present composed of one representative from each of fifteen societies together with three Members at Large.

The constituent societies are:

Amer. Assoc. Petroleum Geologists
Amer. Geographical Society
Amer. Geophysical Union
Amer. Meteorological Society
Amer. Soc. of Photogrammetry
Assoc. of Amer. Geographers
Geological Society of America
Mineralogical Soc. of Amer.
Paleontological Soc. of Amer.
Seismological Soc. of Amer.
Soc. of Economic Geologists
Soc. of Economic Paleontologists and Mineralogists
Soc. of Exploration Geophysicists
Soc. of Vertebrate Paleontology

The organization is handled by a small Executive Committee (six members) and a paid Secretary located in Washington. The Secretary notifies members by circular letter of actions of the Executive Committee and of items of old or new business which are pertinent and which might be brought up for discussion when the entire group meets. An annual meeting is held in Washington in April of each year. The meeting this year was on April 28, 1956.

Unfortunately in April your Representative was in California on an extended stay and since the agenda of the meeting carried nothing of specific interest to SEG he did not go to the trouble and expense of flying East to attend. Formerly each representative was expected to turn in at the Annual Meeting a written report on the condition and activities of his society but a year ago this requirement was cancelled and at present no reports of any kind are required from the constituent societies. All the representative is supposed to do is to attend the meeting.

The business dealt with at this year's meeting, although ranging over a wide variety of problems in the earth sciences, did not bear on subjects directly important to SEG. The same situation existed last year. The subjects covered at the meeting (convened at 10:00 A.M., recessed at 12:30 P.M.) can be summarized as below.

(a) Reports of active committees, most of which had already been distributed by mail. Some of these committees are advisory to other government agencies, as to the Weather Bureau Office of Naval Research, International Geographical Union, and the Atomic Energy Commission—others are technical, as on Clay Minerals, on a Glacial Map of the U.S.A., on the measurement of geologic time, on a National Atlas, on topographical maps illustrating cultural geography, and on Marine Ecology and Paleontology.

(b) Questions as to the nomination of delegates to the 20th International Geological Congress.

(c) Discussion of procedure for nominating the Representatives of Member Societies which make up the Division. Suggested that a slate be prepared by the Division from which the Representative shall be selected by his society. This business, which might be important, is in process.

(d) The three newest activities of the Division were described. (1) A committee on Climatology, advisory to the Weather Bureau, (2) A committee on radioactive waste disposal, advisory to the Atomic Energy Commission, (3) A committee on Geography advisory to the Office of Naval Research to deal with a program of financial support for projects of field research in geography abroad involving an annual expenditure of $50,000. The projects are not necessarily geographical.

Luncheon was served, followed by an afternoon session which was a Congress on Nuclear Geology dealing primarily with age determination.

C. B. BAZZONI

September 1, 1956

ABSTRACT OF MINUTES OF THE ANNUAL COUNCIL MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, ATLANTA, GEORGIA, DECEMBER 27–30, 1955

The Council of the American Association for the Advancement of Science held meetings in Atlanta, Georgia on 27–30 December 1955. President George W. Beadle occupied the chair. Principal items of business were as follows.

1. Election of Dr. Laurence L. Synder as President-elect for 1956.

2. Election of two members of the Board of Directors:

(a) Paul M. Gross, Vice-President, Duke University,

(b) George R. Harrison, Dean of Science, Massachusetts Institute of Technology.

3. Election of Vice-Presidents and Chairmen of the Sections (18 Sections). Section E, Geology and Geography, no nomination had been received.

4. Report of the Chairman of the Board of Directors, Dr. Warren Weaver. The Chairman reported briefly on the action of the Council by mail ballot in withdrawing its plans for the organization of a committee to study and report on the effects of radiation from thermonuclear weapons on the industrial uses of atomic energy. This decision was made when it became generally known that the National Academy of Sciences-National Research Council was planning to appoint a committee for a similar purpose.

5. Report of Administrative Secretary, Mr. Dael Wolfle.

(a) Announcement of the appointment of Graham DuShane as Editor.

(b) Announcement of a changed format of *Science* and the reduction of emphasis on experimental biology in *Science*.

(c) Report on the largest increase in membership in the Association since 1951.

(d) Report on the major emphasis in 1955 on the effort to improve teaching of science and mathematics in high schools.

(e) Report of operating income and expenses.

(f) Report on headquarters building fund. It is noted that the total cost of new Association headquarters building in Washington will amount to approximately $800,000, that gifts and grants committed or actually received during 1955 amounted to $430,000, and that a loan of $175,000 had been arranged to complete the financing of the building construction.

6. Announcement of the election of Section Secretaries.

7. Election of new affiliates and associates.

8. Publication of amendments to the Constitution and Bylaws.

9. Revision of election procedure. Under the newly adopted procedure nominations for the office of President-elect and members of the Board of Directors of the Association are to be made by a nominating committee consisting of 7 members, of whom 2 members shall be named from the Board of Directors by the Board and 5 members are to be members of the Council, elected for two-year terms by the Council at the Annual Council meeting. The committee will present at least 2 nominations for each vacancy on the Board of Directors and for the President-elect. These nominations are to be published officially by October 1 of each year. Additional candidates for any of the elective offices may be nominated and included on the ballot by a petition endorsed by 30 members of the Council and received in the Association's office by November 1. Ballots are to be mailed to the Council by November 10 and must be received in the Association's office by December 10.

10. Increasing Council attendance. The Council discussed the desirability of increasing attendance at Council meetings and voted to request the Board of Directors to study a proposal of making an annual assessment on all affiliated organizations for the purpose of collecting money to be used toward the payment of traveling expenses of Council members to attend the annual meeting.

11. The Association adopted a resolution to the effect that the Annual Meeting of the American Association for the Advancement of Science should be held under such conditions as make possible the attainment of the Association's high objectives which are the furtherance of science and human

welfare. Resolution stated that these objectives cannot be fulfilled if free association of the members is hindered because of race or creed or other unnatural barriers. Subsequent to the adjournment of the Council meeting copies of this resolution were mailed to all Council members. Mailed ballots approved the resolution by a vote of 220 to 28 with 3 not voting.

12. Other resolutions were adopted on the amendment of the McCarran-Walter Act, the approval of the use of funds of the United States through the National Science Foundation to supplement travel costs of United States citizens attending scientific meetings in foreign countries.

Following action of the Board of Directors at its meeting in New York City, October 29–30, 1955, Council members have received reports of the meetings of the Board of Directors held in Washington, D.C., on March 3–4 and June 2–3, 1956. The following items are of interest to members of the Society of Exploration Geophysicists.

1. Each affiliate Society will be requested to contribute to the Association the sum of $25.00 each year for each representative, to be used to help defray the traveling expenses of the Council members who attend Council meetings.

2. The committee on AAAS meetings made recommendations relating to the nature of the Association's meetings.

3. The Board voted to hold a special meeting in Washington, D.C. on October 12, 1956 to commemorate completion of the Association headquarters building.

4. The Board considered a suggestion to explore the possibility of holding an international meeting on oceanography.

5. The Chairman of the Board was instructed to appoint a committee to select a publisher and to recommend procedures for selecting authors of semi-popular books in science.

6. The Board considered a number of suggestions relating to modification of the form and content of *Science* and *Scientific Monthly*.

7. Building progress. The Executive Officer reported completion of loan of $175,000 and the rental of space to American Geological Institute, American Geophysical Union and American Society of Photogrammetry on the third floor of the new building. It was noted that approximately 2,500 sq. ft. still remain available for rent.

8. At the Board meeting June 2–3, 1956, it was noted that a letter of invitation to join the Association had been sent to the Society of Exploration Geophysicists on April 24. This action was evidently caused by a lapse in appointment of an SEG member at that time.

9. The staff was authorized to proceed with arrangements for an international conference on oceanographic problems, probably in 1959.

10. The Board voted to establish a small committee to study the feasibility of a Science Information Center.

11. The Board approved and instructed the Executive Officer to prepare for submission to the Board at its October meeting and to the Council in December, the necessary changes in Constitution and Bylaws to change all associate members to affiliated members. The committee on affiliation suggested more direct liaison with the affiliates, encouragement of their greater identification with AAAS affairs.

The 1956 meeting of the Council and Association will be held in New York City in December.

ROLAND F. BEERS

PROPOSED "ANNUAL ISSUE"

Purposes

1. To gather into one special annual issue of GEOPHYSICS certain nontechnical information, thus releasing space in the four regular issues for technical papers.
2. To provide a source of advertising revenue which will offset the cost of publishing the annual Membership List.
3. To condense information necessary to the management and government of the Society for easier reference, and to publish this information at a more suitable time of the year.

Content

1. SEG officers (with photographs)
2. List of committees
3. Data on local sections
4. Code of ethics
5. Constitution and Bylaws
6. Committee reports
7. Style guide for authors of papers
8. Policy on release of technical papers
9. Description of Annual Meeting
10. Survey of Geophysical Activity
11. Index of Wells Shot for Velocity
12. Survey of education in geophysics (when available)
13. Membership List
14. Statistical analysis of membership
15. Additional material at the discretion of the Editor

Procedure

1. Authority—Composed by the Business Office under the Editor's direction.
2. Date of publication—About one month after the Annual Meeting.
3. Distribution—To all current members and subscribers to GEOPHYSICS.
4. Print Order—Same as for regular issues of GEOPHYSICS.
5. Sale Price—Same as for regular issues of GEOPHYSICS, but included in the current subscription price to non-members.

Schedule

1. Announcement of the first issue must be made a year in advance to secure advertising commitments.
2. First issue December 15, 1957 to contain the material normally published in the regular 1957 issues.

G. A. GRIMM
NORMAN RICKER
COLIN CAMPBELL

Tulsa, Oklahoma
August 29, 1956

ANNOUNCEMENTS

EUROPEAN ASSOCIATION OF EXPLORATION GEOPHYSICISTS

OFFICERS

At the Tenth (Fifth Annual) Meeting of the EAEG officers for the year ending in May, 1957 were elected, as follows:

President: E. H. Hedström, The Electrical Prospecting Co., Stockholm
Vice-President: L. Solaini, Instituto di Geofisica Applicata, Milan
Secretary-Treasurer: B. Baars, Bataafsche Petroleum Mij., The Hague
Editor: O. Koefoed, Bataafsche Petroleum Mij., The Hague

All are active members of the SEG. Mr. Hedström is a Charter Member, and Professor Solaini is currently serving on the Reviews Committee of SEG.

EUROPEAN ASSOCIATION OF EXPLORATION GEOPHYSICISTS AWARDS

At the Eighth Meeting of the EAEG, held in Paris, it was announced that two Awards should be offered to members. The conditions governing these Awards are given below.

1. Two awards shall be given annually, except for the case given below.
2. One award which shall be called the Conrad Schlumberger Award, shall be for a paper written by a member and judged to make a significant advance in geophysical prospecting, or to a member who has made an outstanding contribution to the subject.
3. One award, which shall be called the Van Weelden Award, shall be for the best paper presented at an EAEG meeting by any member, who on the 31 December of the year in which the paper was presented, is under the age of 28 years.
4. The president shall appoint a Panel of five judges to examine the papers and make recommendations for the Awards for the approval of the president. No judge shall serve on the Panel for a period longer than three consecutive years, but any person can be reappointed after the lapse of another three years.
5. The presentation of the awards shall be made at a meeting of the EAEG.
6. The Conrad Schlumberger Award shall consist of a certificate, together with a copy of the volume of the journal, appropriately bound, containing a citation of the award. The Van Weelden Award shall consist of a certificate, a copy of the volume of the journal, appropriately bound, containing a citation of the award, and a sum of 300 guilders.
7. At the discretion of the Panel of Judges, either or both awards may be withheld in any year.

Citation for the Conrad Schlumberger Award

One of the most important contributions to the methods of geophysical prospecting in the year 1955 has been in the field of electrical investigations and has taken the form of the publication of methods and data for the interpretation of field resistivity observations. Two of these publications are of especial significance: "Abaques de sondage électrique" by La Compagnie Générale de Géophysique and "A Practical Method of Calculating Geoelectrical Model Graphs for Horizontally Stratified Media" by H. Flathe. Both these papers, of great practical value and adding materially to the technique of analyzing field observations, are of similar high merit. But whereas the contribution by La Compagnie Générale de Géophysique is the result of a collective effort on the part of a number of individuals who have advanced theory, the paper by H. Flathe represents the work of a single individual. On these grounds the President of the European Association of Exploration Geophysicists, in accordance with the recommendations of the Awards Committee, has decided that the Conrad Schlumberger Award for 1955 be presented to H. Flathe for his practical contribution to the theory of interpretation embodied in his paper cited above.

It is satisfying and appropriate that the first Conrad Schlumberger Award has been given for a paper falling within the field of prospecting in which Conrad Schlumberger himself had such a great interest and in which he has made such outstanding advances.

Citation for the Van Weelden Award

The President of the European Association of Exploration Geophysicists, in accordance with the recommendations of the Awards Committee, has decided that the Van Weelden Award for the year 1955 be presented to E. W. Carpenter for his paper entitled "Some Notes Concerning the Wenner Configuration."

This paper contains a novel approach to the treatment of the well-known four-electrode Wenner arrangement. By combining the electrodes in pairs, three apparent resistivities are defined and a relation between them obtained. By applying his ideas to theoretical cases, the author demonstrates the possibility of differentiating between lateral and vertical variations of resistivity, a problem which has formed one of the major difficulties in field resistivity measurements.

OHIO OIL COMPANY DENVER RESEARCH CENTER

Three days of dedication and open house officially opened the Ohio Oil Company's Denver Research Center, 7400 South Broadway, Littleton, Colo., Oct. 17–18–19. The events culminated Friday Oct. 19 with a public open house from 2 to 9 P.M.

On hand to welcome visitors were Ohio Oil's president J. C. Donnell II and W. H. Barlow, manager of the company's research department, and other officials from the General Office at Findlay, Ohio, as well as Dr. W. J. Yost, research director at the center, and members of his staff.

The public opening Friday featured guided tours in which the entire center, including the modern laboratories, were shown and explained to visitors. An extensive photographic display of Ohio Oil's widespread activities was also on view. Ample parking space was available and refreshments were served.

The dedication ceremony Wednesday included addresses by United States Sen. Gordon L. Allott of Colorado and Donnell. In attendance by special invitation were business associates of Ohio Oil, who later toured the center.

Activities Thursday featured a talk to invited guests from the education and research fields by Dr. W. V. Houston, president of Rice Institute, Houston, Texas, and Ohio Oil President Donnell. Houston discussed the relationship between academic and industrial research and Donnell talked on research objectives of the Ohio Oil Company. The ceremony was followed by a tour of the center.

The three-day events held during Oil Progress Week at the Research Center, climaxed work which was started early in 1955 with the purchase of the 80-acre tract 11 miles south of downtown Denver. At the April groundbreaking ceremony, Ohio Oil's president said that the site was chosen because of the "fine scientific environment which exists in the general area. The faculty and staff members of the many universities and research organizations already here will stimulate our scientists and their research efforts."

Donnell has noted that to "make progress—even to survive—in one of America's most competitive industries, an oil company must look constantly and constructively to the future." The center, he said, will "assist management in directing the company's energies into the most productive channels."

Barlow, manager of the research department, said that "It is anticipated when we get up to full staff our annual expenditures will be more than a million dollars a year at the Research Center."

Yost, director of the Center, will coordinate the activities of some 75 scientists in their research in petroleum and allied fields. The technical staff is in four sections. Heading the **geology** section is Dr. R. D. Russell; **physics** section, Dr. J. E. White; **engineering** section, Dr. F. H. Poettmann; and **chemistry** section, Dr. L. C. Gibbons, J. W. Bruskotter heads the business section and P. L. Knapp is research librarian.

Commenting on future plans for the center, Yost explained that Ohio Oil expects to double

the size of the wing containing the laboratories within a few years. This will increase the present 45,000 square feet of floor space to 63,000 square feet.

CALGARY SECTION GOLF TOURNAMENT

The Fourth Annual Doodlebug Golf Tournament, sponsored by the Canadian Society of Exploration Geophysicists, was held September 8th, 9th and 10th at the Banff Springs Hotel Golf Course, Banff National Park, Alberta. As in years previous the Tournament was well attended by Geophysicists from all parts of Canada and the United States. The Doodlebug (Championship) Flight was won by Vic Familinow of Western Leaseholds, Limited. The Runner-Up was Doug Drysdale of Texaco Exploration.

A total of one hundred and sixty participants competed in twenty flights for over one hundred trophies and prizes. The winner of each flight received a small ceramic statue depicting a separate operational phase of Geophysics.

A cocktail party, buffet dinner and bridge-tea for the ladies made up a portion of the entertainment program. Plans are underway for an even more eventful program for the Fifth Annual Tournament to be held next summer on a date as yet unspecified.

The picturesque Banff Springs Hotel Golf Course in the Heart of the Rockies was in excellent condition. It was bathed by typical Southern Alberta sunshine during the three days of competition.

Winners of the various flights were:

4TH ANNUAL "DOODLEBUG" GOLF TOURNAMENT WINNERS

Flight	*Winner*	*Runner-Up*	*Consolation Winner*	*Medalist*
Doodlebug	Vic Familinow	Doug Drysdale	Walt Holden	Jack Cush
Supervisors	Bill Whyte	D. K. Seaman	Fred Brechtel	Tom Lymunstull
Party Chiefs	Arvil Minor	Bruce Bailley	Angus MacKenzie	Jack Setters
Interpreters	Paul Kahler	Murray Hyde	Don Seaman	Milt Hinson

Vic Familinow, winner of the Doodlebug (Championship) Flight, is presented the Hawthorne Trophy by Mr. R. M. Thornton, Jr., President of Herb J. Hawthorne, Inc. of Houston, Texas. Assisting in the ceremony are, from left to right, Jack Setters, 1956 Tournament Chairman; Familinow, Thornton, Lena Wolfe, Seismic Service Supply and Ralph B. Ross, President of the Canadian Society of Exploration Geophysicists.

Flight	*Winner*	*Runner-Up*	*Consolation Winner*	*Medalist*
Computers	Norm Willson	Ed Dodd	Les Vye	Frank Hickey
Shot Hole Inspectors	Al Barlow	Angus Moss	John Stevaluk	Carey Gunn
Surveyors	Glen Johnston	Dunc Robinson	Sam Mozelle	Mac Baker
Permitmans	Ernie Crough	Dave Smith	Dave Hunter	Gordie Hess
Rodmans	Corby Hart	Hugo Renden	J. O. Rogers	Dick Benish
Observers	Ray Wright	Burt Wade	Jack Anderson	Jack Ainsworth
Reel Truck Drivers	Howard Mallabone	Jim Farley	Norm Martinson	Dan Saga
Shooters	Jack Bowden	George Garbutt	Jack Campbell	Ben Erhardt
Drillers	Lew Stevens	Wilf Turner	Jim Murphy	Rick Ferrell
Water Jacks	Norm Edwards	Nace McGee	Tony Lee	Spence Claus
Preloaders	Bill Moyer	Mac Parker	Giles Wilderman	Pete Savage
Party Managers	Pete Todesco	Sam Patterson	Syd Kahonoff	Hank Zimmer
Scouts	Orry Gorgichuck	Nash Miller	George Brown	T. A. Hallbrook
Draftsman	Lyall Campbell	Swede Erickson	Rod MacKenzie	Lloyd Lewis
Bird Dogs	Lou Castelli	Allan Campbell	John Lawson	Jack Robinson
Jug Heads	John O'Rourke	Jack Williamson	John Johnson	Gordon Gibson

Doug Drysdale, Runner-Up, congratulates Vic Familinow, winner of the fourth annual C.S.E.G. "Doodlebug" Golf Tournament. Looking on at extreme left is Jack Setters, Tournament Committee Chairman, and at right Ralph B. Ross, President of the CSEG and R. M. Thornton, Jr., President of Herb J. Hawthorne, Inc. of Houston, Texas.

D. Q. Barton, Vice-President of Electro-Technical Labs (Canada), Ltd. presents the Electro-Tech Trophy to T. J. McCubbin.

HOUSTON SECTION GOLF TOURNAMENT

The first meeting of the Houston Section for the 1956–1957 season was the annual Barbecue-Golf Tournament at the Texaco Country Club, September 21st. Approximately 150 members attended.

A golf trophy, named the Peanuts Palmer Trophy, was presented to the Houston Section by several of the members. The trophy is so named in grateful recognition of the service R. L. "Peanuts" Palmer, McCollum Exploration Company, has contributed to each Golf Tournament. Peanuts also was named the Permanent Golf Tournament Chairman.

Merchandise certificates were awarded to the following golfers:

Low net score	J. M. Kendall, The Texas Company
Low gross score	Kenneth Love, Tidewater Oil Company
Most 7's	W. G. Noonan, Marine Exploration Company
Most birdies	Sherman Clark, McCollum Exploration Company
Most pars	Kenneth Love, Tidewater Oil Company
Lowest on hole 11	P. C. Barbour, Gulf Oil Corporation
Highest on hole 14	Steve Turner, Vector Manufacturing Company
Door prize	Kenneth Webb, Seismic Explorations, Inc.

Kenneth Love made the low gross score and his name will be engraved on the Peanuts Palmer Trophy as the 1956–1957 Houston Section champion.

CIVIL SERVICE EXAMINATIONS

The United States Civil Service Commission has announced an examination for Geophysicists (Exploration) for filling positions in the Geological Survey, Department of the Interior, and various other agencies in Washington, D. C., and throughout the United States. Some positions may be

filled in United States Territories and Possessions, and in foreign countries. The entrance salaries range from $3,670 to $11,610 a year.

Appropriate education and experience are required. For positions paying $3,670 and $4,525, education alone may be qualifying. No written test is required.

Further information and application forms may be obtained at many post offices throughout the country, or from the U. S. Civil Service Commission, Washington 25, D. C. Applications will be accepted by the Board of U. S. Civil Service Examiners, Geological Survey, Department of the Interior, Washington 25, D. C., until further notice.

POSTDOCTORAL FELLOWSHIP OF SIGMA DELTA EPSILON GRADUATE WOMEN'S SCIENTIFIC FRATERNITY

$1,600

Applications for the year 1957–1958 should be submitted before February 1, 1957 to the Fellowship Awards Board which is authorized to make the seventh Sigma Delta Epsilon Fellowship Award.

Women with the equivalent of a Ph.D. degree, carrying on research in the mathematical, physical, or biological sciences, who need financial assistance and give evidence of high ability and promise are eligible. During the term of her appointment the appointee must devote the major part of her time to the approved research project, and not engage in other work for remuneration (unless such work shall have received the written approval of the Board before the award of the fellowship).

Application blanks may be obtained from Dr. Dorothy Quiggle, Petroleum Refining Laboratory, The Pennsylvania State University, University Park, Pennsylvania. Announcement of the award will be made early in March 1957.

CIVILIAN INVENTIVE TALENT NEEDED TO SOLVE U. S. DEFENSE PROBLEMS

If you are an inventor, professional or amateur, you may have the germ of an idea in the back of your mind which could be the solution to one of the technical problems currently affecting national defense, according to the National Inventors Council, U. S. Department of Commerce.

Many of the nation's civilian inventors have contributed their brain-power toward solution of problems for the Armed Forces and have conceived ideas which have saved many lives and dollars. Over 200 of these successful inventions have been channeled through the National Inventors Council, which since 1940 has served as liaison agency between inventors and the military services.

To obtain a copy of the current "Technical Problems Affecting National Defense," write to NIC, U. S. Department of Commerce, Washington 25, D. C.

CONTRACT GIVEN FOR PRELIMINARY ARCHITECTURAL PLAN FOR NEW ENGINEERING CENTER IN MID-TOWN MANHATTAN

United Engineering Trustees, Inc., the joint corporate agency of the four major national engineering societies, has signed a contract for preliminary architectural plans and studies for a new Engineering Center in mid-Manhattan, New York City. This is the first definite step toward construction of what is expected to make New York the "engineering capital of the world."

Announcement of the granting of the contract came with announcement of the reelection of Walter J. Barrett, of Glen Ridge, New Jersey, as President of United Engineering Trustees, Inc. (UET). It was, also, the first formal revelation that all the four member societies of UET, and a fifth that is expected to become a member, had voted, through their governing boards, to remain in New York. Several other cities had striven to obtain the Center.

The architects named are Shreve, Lamb and Harmon Associates, of 11 East 44th Street, New York, designers of the Empire State Building and more recently the new Brooklyn Supreme Court Building. The announcement did not indicate any details as to specific location, cost or time of completion.

The present 16-story quarters, known as the Engineering Societies Building, house the four "Founder Societies," the American Society of Civil Engineers, the American Institute of Mining, Metallurgical and Petroleum Eingineers, The American Society of Mechanical Engineers and the American Institute of Electrical Engineers. A fifth prospective "Founder Society," the American Institute of Chemical Engineers will be included in the Center project. At a recent meeting at which Mr. Barrett was re-elected and the architectural contract granted, the Board of Trustees of UET approved the American Institute of Chemical Engineers as a member. This action awaits ratification of the other four Societies.

W. M. RUST, JR., WILL SPEAK AT RICE INSTITUTE MEETING

Engineering graphics teachers from colleges throughout the nation will meet at the Rice Institute, Houston, Texas, from January 30 through February 2, 1957.

The annual mid-winter meeting of the Engineering Drawing Division of the American Society for Engineering Education will include eight technical papers and two technical inspection trips. The role of graphical methods in modern engineering procedures will be emphasized.

Following a report on the use of exploration information in oil field development by J. S. Blanton of the Scurlock Oil Company on January 31, ASEE members will visit the Pierce Junction Oil Field to inspect drilling operations and field production problems. A field trip to the Galveston area is planned for Saturday, February 2.

At a banquet on Friday evening in the Rice Institute Commons, Dr. Carey Croneis, Provost of Rice and head of the Institute's Geology Department, will speak on "South America in Color."

Other speakers at technical sessions will include Professor Steven A. Coons of the Massachusets Institute of Technology, Professor S. B. Elrod of Purdue University, Dr. L. D. Haskew of the University of Texas, Professor J. R. Holmes of the University of Texas, Dr. W. M. Rust of the Humble Oil and Refining Company, Professor J. R. Sims of Rice Institute, and Professor C. H. Springer of the University of Illinois.

The Houston chairman for local arrangements is Professor A. P. McDonald, head of the department of Engineering Drawing at Rice. Registration will be at the Shamrock Hotel, Houston, and all sessions will be at the Rice Institute campus.

The Rice Institute is a privately supported, tuition-free, co-educational university. It has approximately 1800 students, 350 of them enrolled for graduate study.

SAFETY MEETING AIDS

The Atlas Powder Company has announced release of their new movie, "How to Handle Women and Explosives." Previews indicate a WOW! It is a 17½ minute black and white 16 mm film which will be loaned free of charge along with all the materials needed for a complete safety meeting by writing Mr. J. H. Dannenberg, Advertising Manager, Atlas Powder Company, Wilmington, Delaware. Mr. Dannenberg will also furnish on request a series of three new safety posters for each crew's bulletin board.

The DuPont Company has announced its release of three different series of 35 mm color transparencies showing typical seismic operations in high-land, off-shore and swamp and marsh. Emphasis is placed on the proper methods for handling and using explosives in these vastly different types of work. The program of the series appropriate to your area is available through your local DuPont representative.

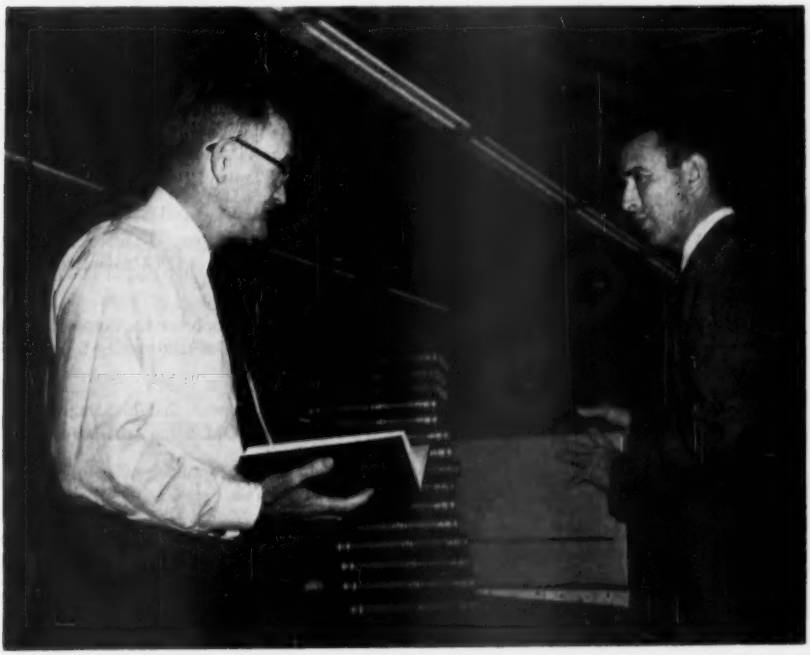
THE SAFETY COMMITTEE

PERSONAL ITEMS

Members of the Society are invited to notify the business manager of any changes in their positions or companies for announcement in this section. Members are further invited to check with the public relations departments of their companies to assure that the Society is on their mailing lists to receive publicity releases.

GEORGE P. WOOLLARD, Associate Professor in the University of Wisconsin Department of Geology, was honored at a luncheon of the Georgia Tech Student Section of the SEG November 13, 1956, during his visit to the campus of Georgia Institute of Technology. While there he spoke on "Some major problems concerning the earth" and "Crustal structure of the earth as recorded by geophysical studies" in two public addresses. On the following day he presented the paper, "The program of the U.S.A. in the International Geophysical Year," at a joint meeting of the Georgia Tech, Emory and RESA chapters of The Sigma Xi.

ROBERT L. KIDD, formerly President of Arkansas Fuel Oil Co., Shreveport, has been elected President of Cities Service Oil Company (Del.) and now resides in Bartlesville, Oklahoma.



Dallas, Texas—A complete, bound set of GEOPHYSICS, Vols. 1 through 18, has been presented to the geology library of the University of Western Australia by CECIL H. GREEN, board chairman of Geophysical Service, Inc.

Mr. Green, left, is shown examining the volumes prior to their shipment to Australia. With Mr. Green is R. C. DUNLAP, JR., a GSI vice-president and president of the Society of Exploration Geophysicists.

J. C. De Bremaecker, after one year spent at Lamont Geological Observatory, Columbia University, has resumed his duties as geophysicist with the Institute for Scientific Research in Central Africa, Bukavu, Belgian Congo.

R. C. Dunlap, Jr., Past President of the Society of Exploration Geophysicists, underwent a "spinal fusion" last September in Dallas. As this issue went to press he was recuperating satisfactorily, and it was believed the operation would be successful.

Gabor Dessau has returned from the Geological Congress in Mexico to his assignment as UNESCO expert with the Israel Institute of Technology in Haifa. His task is the establishment of a mining engineering department. He will stay in Haifa for another year, and then return to his academic and consulting activities in Italy.

Jack L. Mataya has been transferred to Midland, Texas, as district geophysicist for Stanolind Oil and Gas Company. Mataya succeeds C. J. Long, who became division geophysical supervisor at Fort Worth last month.

R. E. McMillen rejoined Midstates Oil Corporation of Tulsa, Oklahoma as Chief Geophysicist in July after spending three months in Europe and Africa. From early April to mid June he was retained as geophysical exploration adviser to the Bureau de Recherches de Petrole in Paris, France. While on this assignment he was concerned with various exploratory ventures in metropolitan France and in French Equatorial Africa.

Kazim Ergin, who has been the director of geology, Department of Mineral Research and Exploration Institute (M.T.A.) of Turkey, has resigned from that post and is now professor of applied geophysics at the Mining Engineering Department of the Technical University at Istanbul. His present address is: Teknik Üniversite Maden Fakültesi, Istanbul, Turkey.

D. D. Mize, President and general manager of Electro-Technical Labs. (Houston, Texas) announces that construction has begun on a $450,000 building for new quarters. The offices and plant will be of modern design, air conditioned throughout, located on three acres at Glenmont and Sixth Streets in Houston near Bellaire.

William W. Green, manager of the Egyptian division of Seismograph Service Corporation recently returned to the U. S. on a 2 month vacation which he spent in Colorado visiting friends and relatives.

Cecil V. Hagen, President of Venezuela Syndicate, has announced that his company has acquired the assets of Talon Petroleum, C.A., and has entered the oil exploration field in Venezuela.

C. T. MacAllister, after many years in geophysics, has opened a consulting office in Houston, Texas. Until suitable office space is available, his office will be at home, 6327 Vanderbilt Street.

Sohio Petroleum Company Exploration Division has received the National Safety Council Award of Merit, as a result of an outstanding safety record in 1955.

O. C. Clifford, Jr., chief geophysicist of the Atlantic Refining Co., Crude Oil Production Dept., has announced that his company presented a torsion balance to Lehigh University. The instrument will be used by the university's Department of Mining Engineering in lab experiments or field demonstrations.

S. J. Pirson, Professor of Petroleum Engineering at the University of Texas, on October 23 presented a talk before the Fort Worth section of the AIME entitled: "Comprehensive Well Log Interpretation." In addition to a review of current techniques of electric and radioactivity log interpretation, new techniques for the interpretation of shaly sands and oil-wet reservoir rocks were

offered together with methods to predict well productivity, fluid production ratios, flow potentials and recovery from logs.

GEOPHYSICAL OPERATIONS IN SOUTH LOUISIANA are portrayed in "Operation Swamp," a 16 mm sound color motion picture produced by Southern Geophysical Company, Fort Worth.

First showing of the new film was at the New Orleans district meeting of the Oil Industry Information Committee October 15, 1956.

The 15-minute film reviews the work of seismic and gravity crews in the jungles and marshes of one of the current "hot spots" of petroleum exploration.

The film is available on loan to petroleum societies and student engineer groups from The Cain Organization, Inc., 3906 Lemmon Avenue, Dallas 19, Texas.

RECIPIENTS OF 16 STANOLIND FOUNDATION FELLOWSHIPS at 15 colleges and universities have been announced by the institutions and the Foundation.

The fellowship grants provide for graduate work in seven basic fields of study. Each fellowship pays all tuition and fees for the recipient, and provides him with a $1500 stipend for the academic year. John B. Cameron, University of California, Berkeley; Paul W. Pomeroy, Columbia University, New York and Glenn S. Smith, University of Utah, Salt Lake City, received geophysics fellowships.

GEORGE W. SANDER has resigned from his position as geophysicist of Technical Mine Consultants Ltd. and has established his own office as a consultant in Oakville, Ontario, close to Toronto, Canada.

ELDER TRAILER & BODY, INC., of Denver, Colorado, moved recently into a new and larger plant containing 12,000 square feet of working area under roof, according to F. E. McGrath, president. The new address is 4830 Race, Denver, Colorado.

NEAL CLAYTON has become staff geophysicist for Sohio Petroleum Co. with office at 1300 Skirvin Tower, Oklahoma City. He was formerly president of Liberty Exploration Co., Tulsa.

O. B. BENNETT, party chief for Amerada Petroleum Corporation, spoke on the organization and operation for exploration geophysics before a meeting of the Desk & Derrick Club of Williston, North Dakota, December 3, 1956. The Shell Oil Company film, "Prospecting for Petroleum," was shown also.

CALENDAR OF MEETINGS

1957

January

30– 2 American Physical Society Annual Meeting, Hotel New Yorker, New York, N. Y. (K. K. Darrow, Columbia University, New York 27, N. Y.)

February

24–28 AIME Annual Meeting, Roosevelt Hotel, New Orleans, Louisiana

March

1– 2 American Physical Society, University of Oklahoma, Norman, Oklahoma (K. K. Darrow, Columbia University, New York 27, N. Y.)

13–15 Tenth Annual Midwestern Meeting, Society of Exploration Geophysicists, Hotel Texas, Fort Worth, Texas (Colin C. Campbell, Box 1536, Tulsa, Oklahoma)

April

1– 4 American Association of Petroleum Geologists 42nd Annual Meeting—and Society of Economic Paleontologists and Mineralogists 31st Annual Meeting, Kiel Auditorium and Jefferson Hotel, St. Louis, Missouri (E. W. Ellsworth, Box 979, Tulsa, Oklahoma)

25–27 American Physical Society, Washington, D. C. (K. K. Darrow, Columbia University, New York 27, N. Y.)

May

23–25 Acoustical Society of America, New York, N. Y.

September

3–14 International Union of Geodesy and Geophysics Eleventh General Assembly, Toronto, Ontario, Canada (Dr. J. A. Jacobs, 49 St. George St., Toronto, Ontario, Canada)

October

24–26 Acoustical Society of America, Ann Arbor, Michigan

November

10–15 Society of Exploration Geophysicists 27th Annual Meeting, Statler-Hilton Hotel, Dallas, Texas (Colin C. Campbell, Box 1536, Tulsa, Oklahoma)

1958

13–16 Society of Exploration Geophysicists, 28th Annual Meeting, Hotel Gunter, San Antonio, Texas

July 1, 1957 to December 31, 1958

International Geophysical Year. (Worldwide) vide GEOPHYSICS, v. 21, p. 257–259, and v. 21, p. 681–690.

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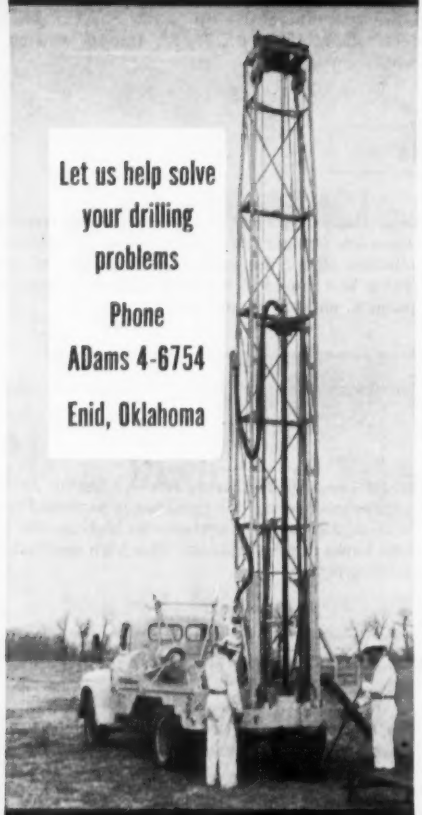

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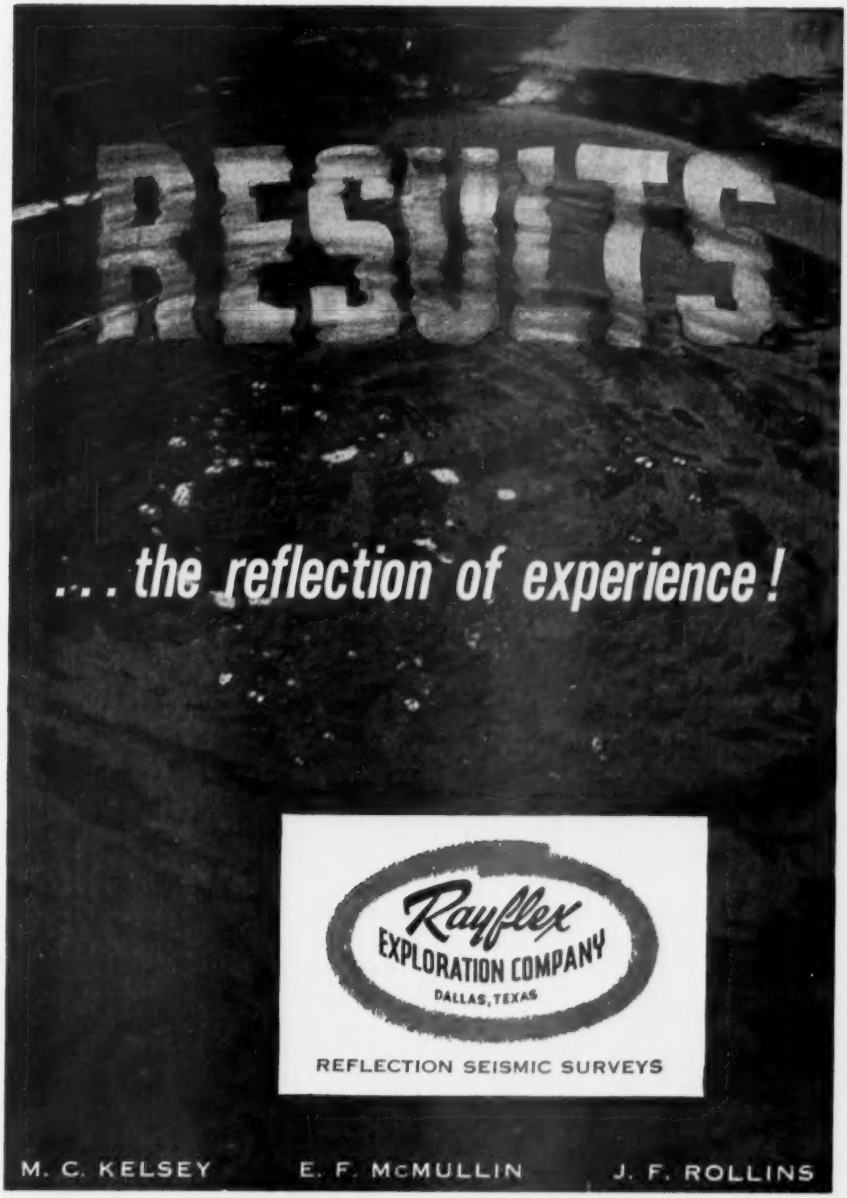
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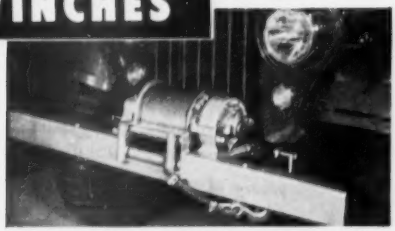

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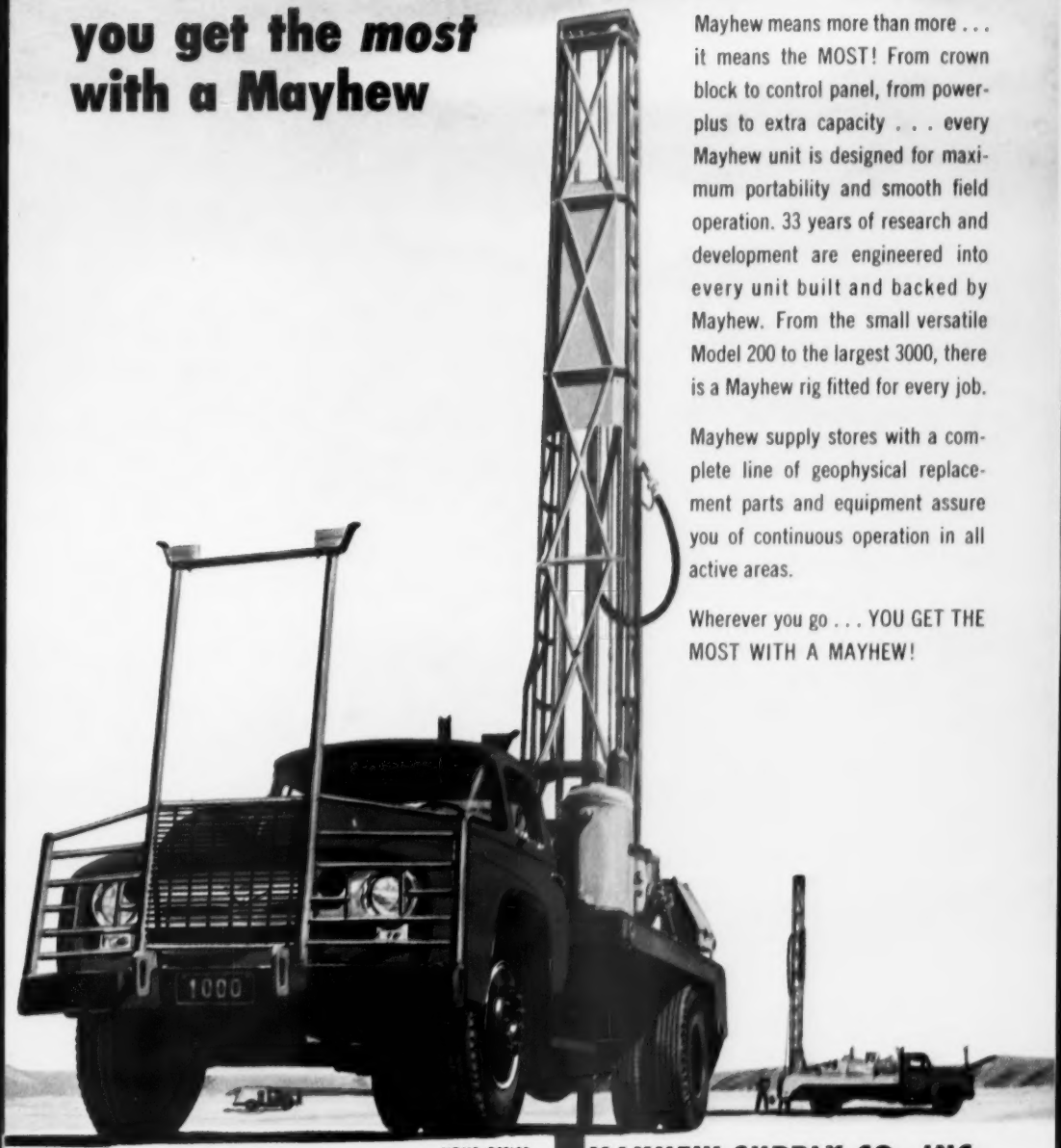

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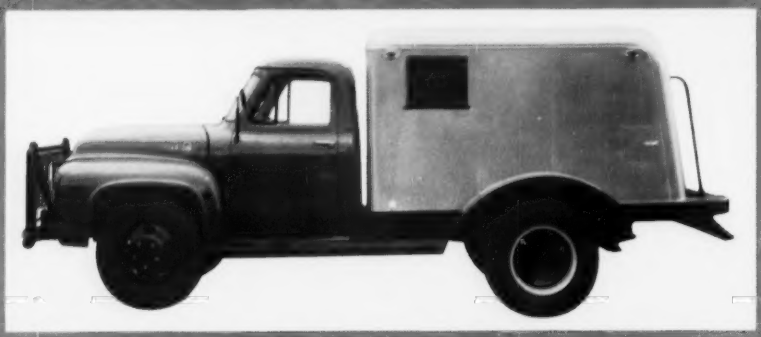

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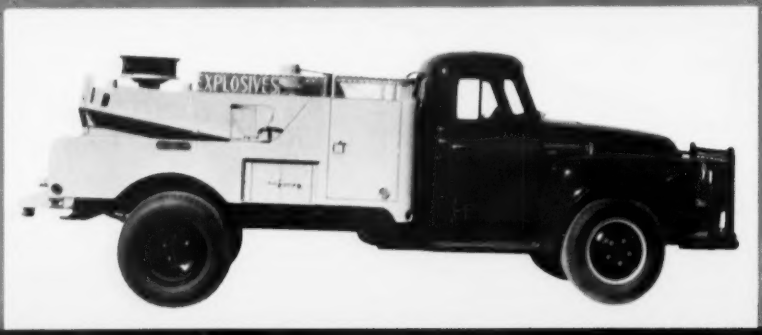

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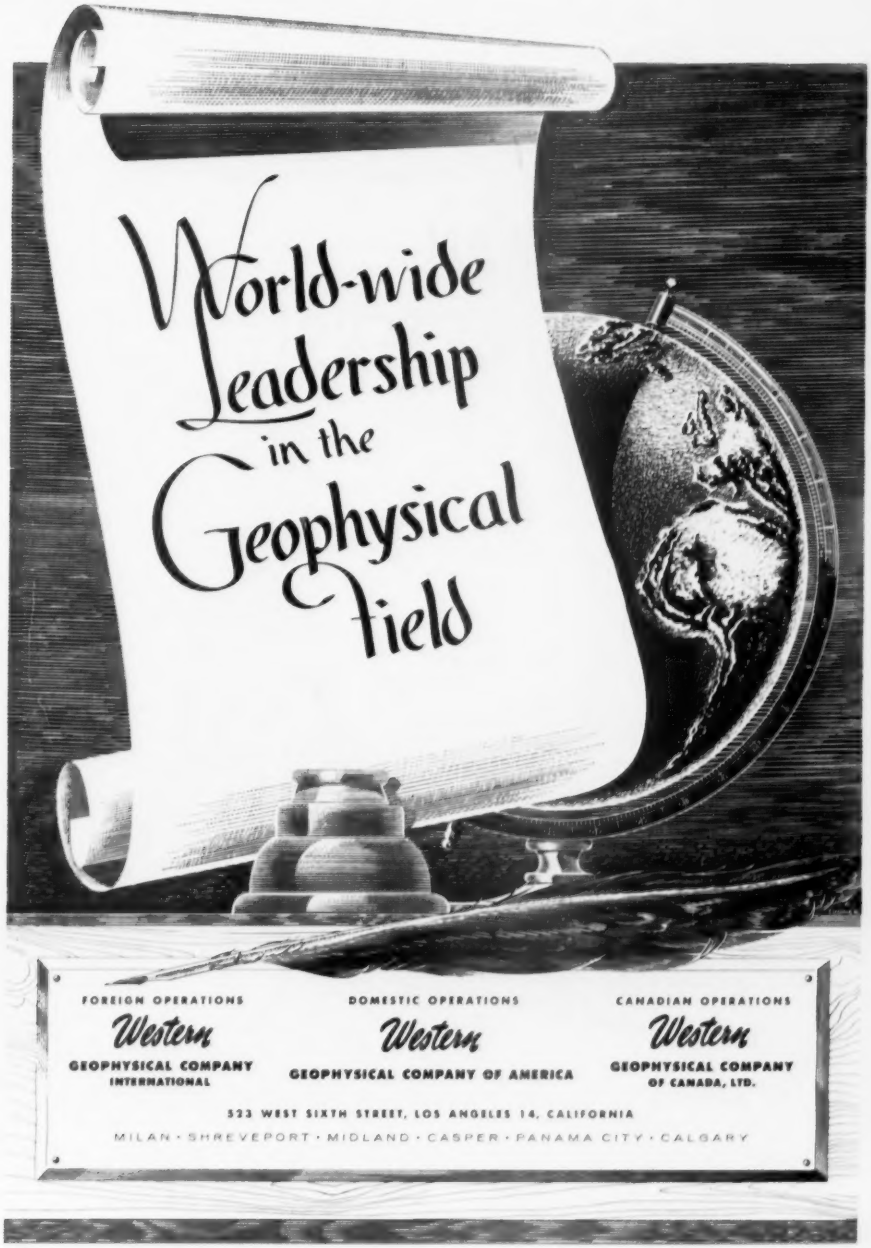
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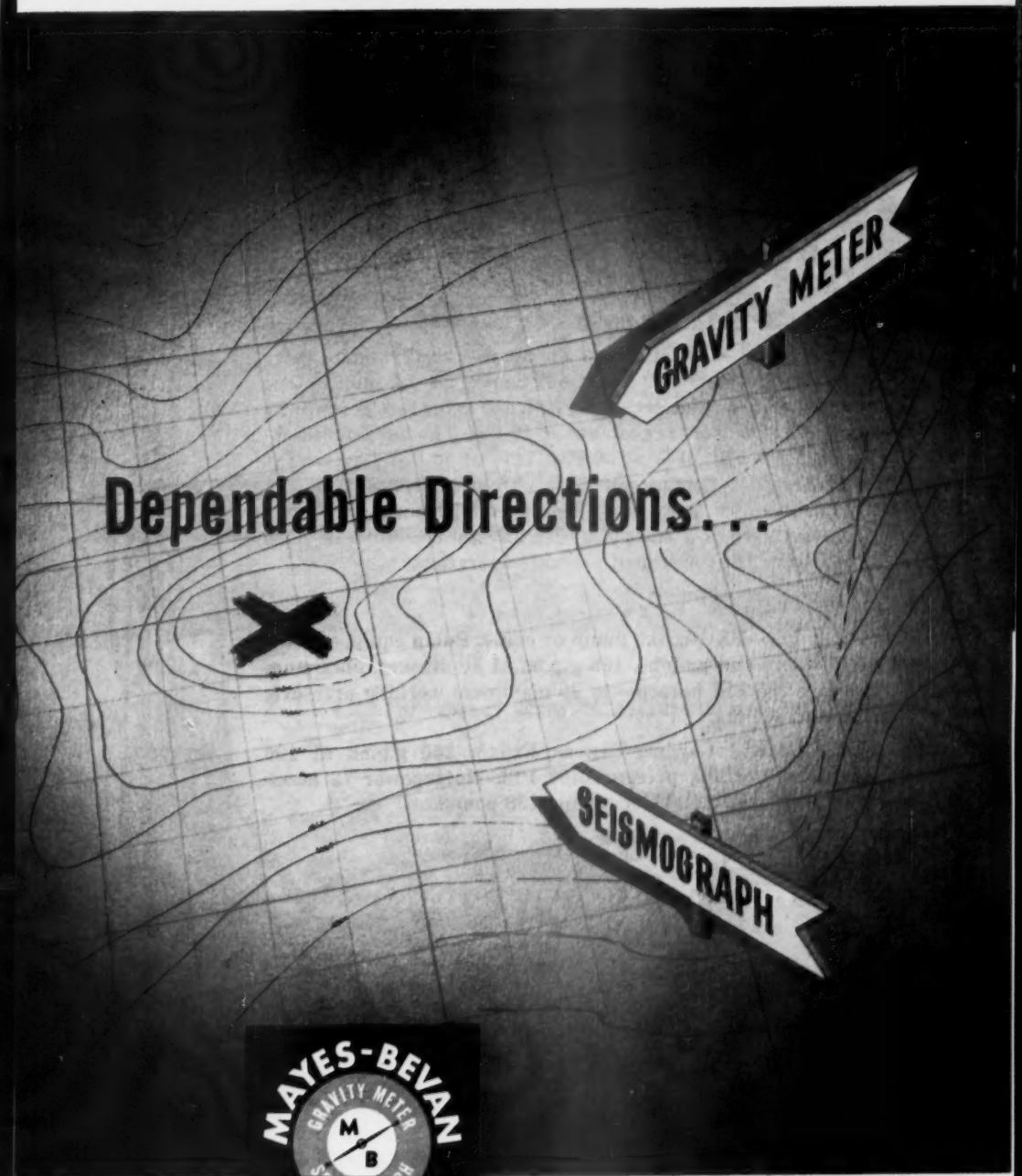

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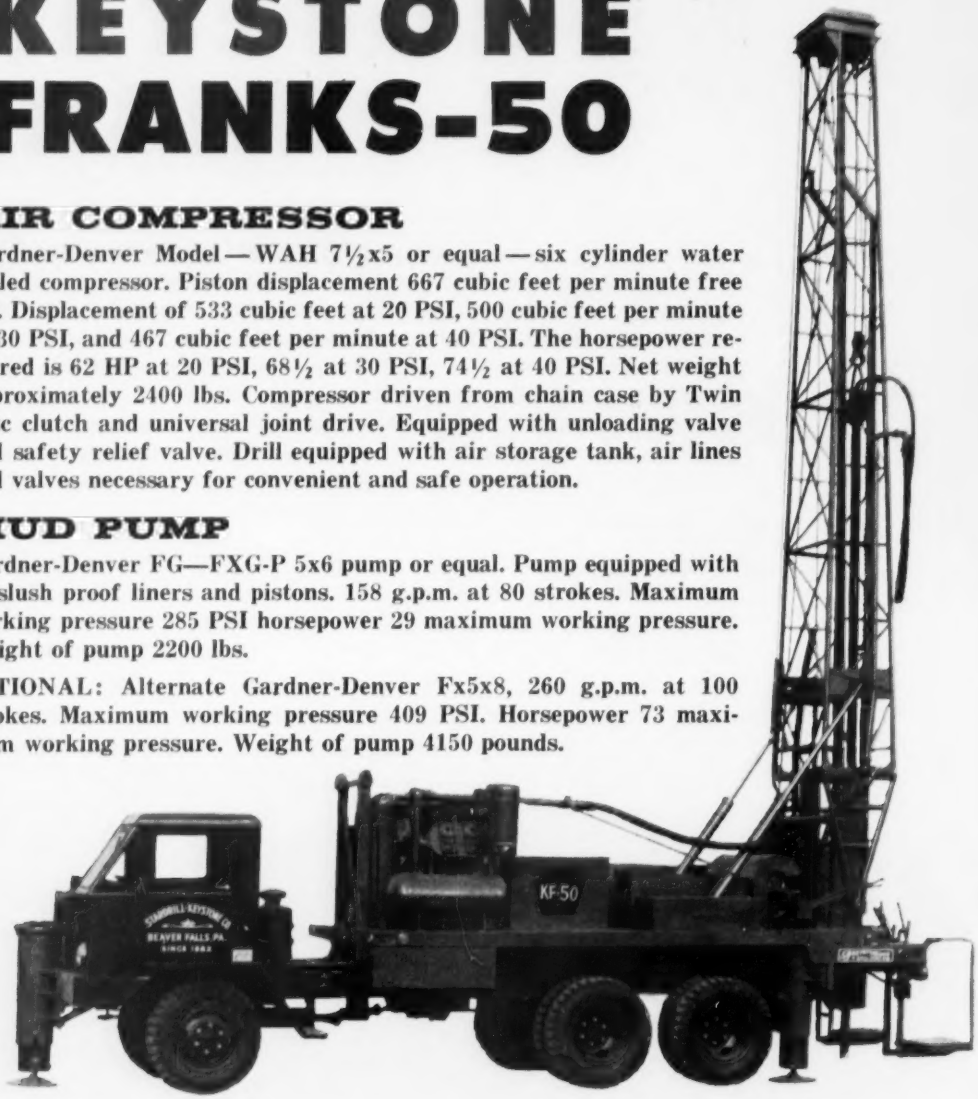

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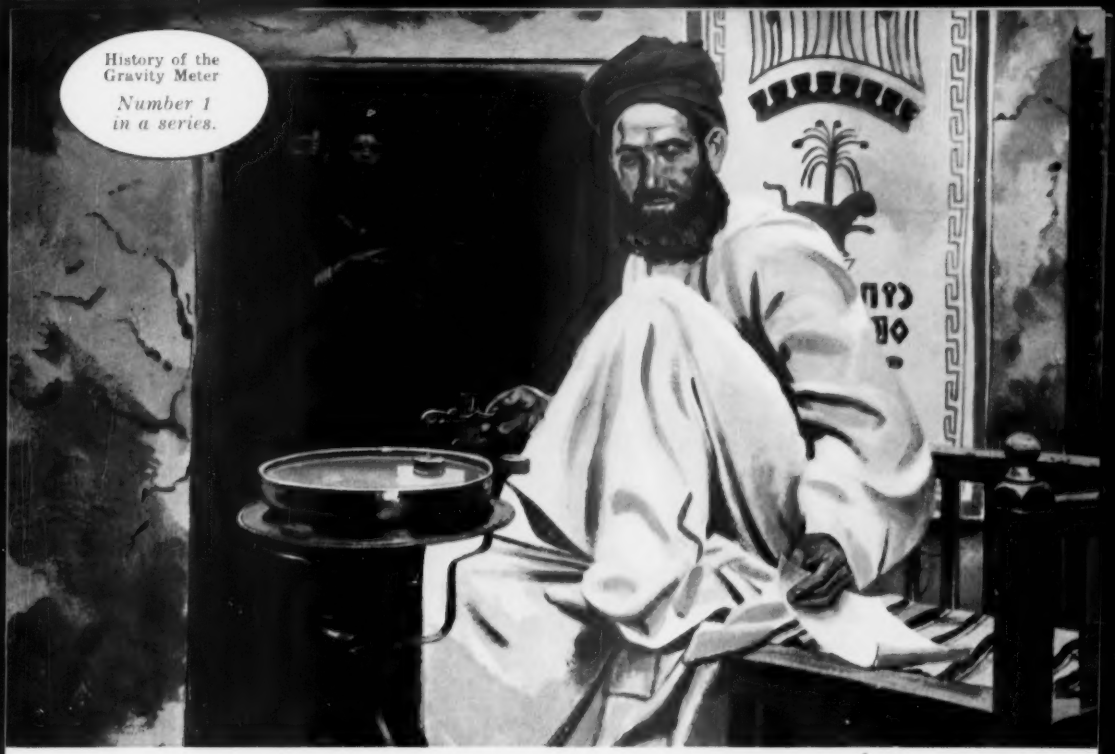

Al-Khazini and the Balance of Wisdom

In the 12th century Al-Khazini, an Arab, conducted experiments with a crude hydrostatic balance and recorded his findings on the phenomena of gravity in the *Book of the Balance of Wisdom*. His theorems as translated and recapitulated are in part:

1. When a body moves in a liquid, one interferes with the other; and therefore water interferes with the body of any thing heavy which is plunged into it, and impairs its force and its gravity, in proportion to its body . . . this interference, in the case of the balance of wisdom, is called the rising up of the beam.
2. When a body is weighed in air, and afterwards in the water-bowl, the beam of the balance rises, in proportion to the weight of the water which is equal in volume to the body weighed; and therefore, when the counterpoises are proportionally lessened, the beam is brought to an equilibrium, parallel with the plane of the horizon.

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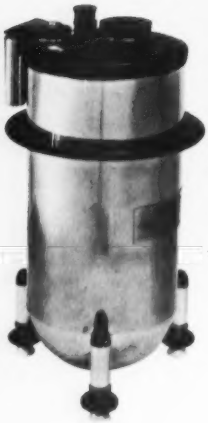
Hugh Traphagen (left) and Stewart Gunson explain the operation of the Worden Gravity Meter to Lieutenant Commander J. E. Moore, captain of the Telemachus.

Gravity Survey of South Pacific floor made in Australian Submarine TELEMACHUS



AGAIN the Worden Gravity Meter proves its rugged dependability and accuracy under extreme and unusual operating conditions. Used previously in the conquest of Mount Godwin Austen in Pakistan, now the Worden meter has been used in the Royal Navy submarine *Telemachus* to study the thickness and composition of the earth's crust beneath the ocean floor.

In one of Australia's first contributions to the International Geophysical Year, the expedition cruised 7200 miles in an area bounded by New Zealand, Fiji Islands, and New South Wales. Diving to undisturbed waters some 220 feet beneath the surface, Mr. Hugh Traphagen of the Lamont Geological Observatory, New York, and Mr. Stewart Gunson of the Australian Bureau of Geology and Geophysics made 125 gravity readings from their cramped laboratory in the ammunition magazine of the submarine.

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To show how advanced Choko's thinking was, nearly sixteen hundred years elapsed before De Haute Feuille (1703) developed a similar principle. This Frenchman used a half sphere with a bowl of mercury at the top and channels down the side—the passage of earthquake waves caused the mercury to run down a particular channel into a cup.

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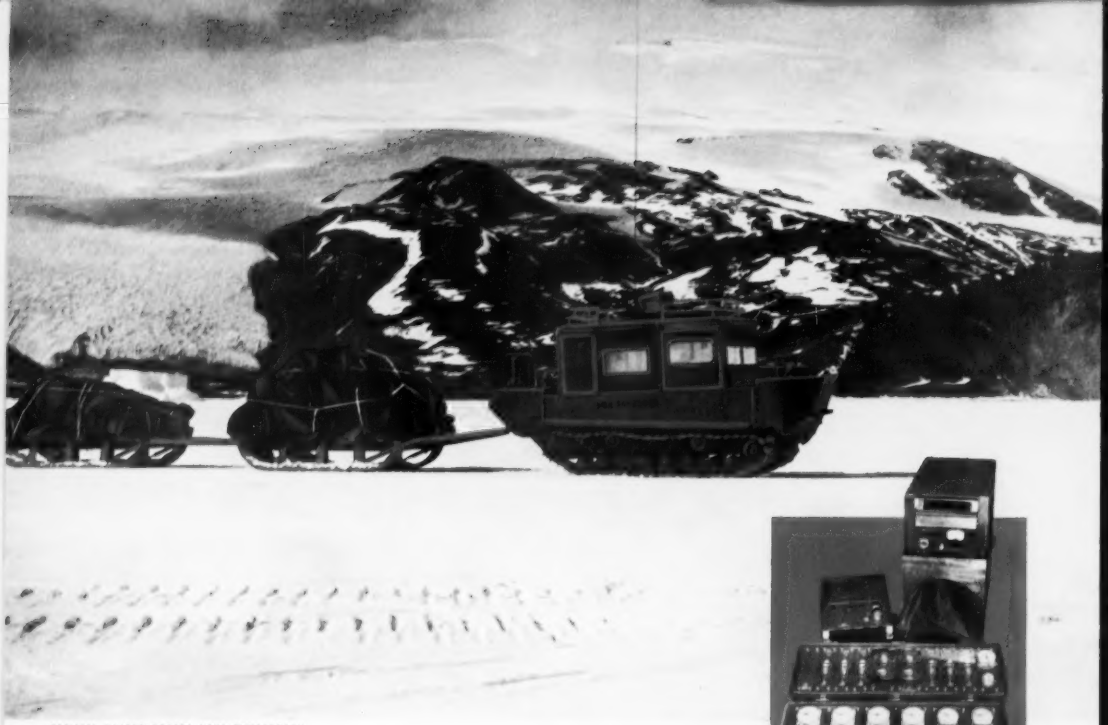

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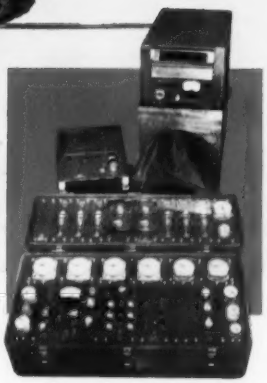

7000B Portable Seismograph showing RS-8U camera, dynamotor, control panel, and one bank of six amplifiers (IGY systems have four banks of six amplifiers, or 24 traces).

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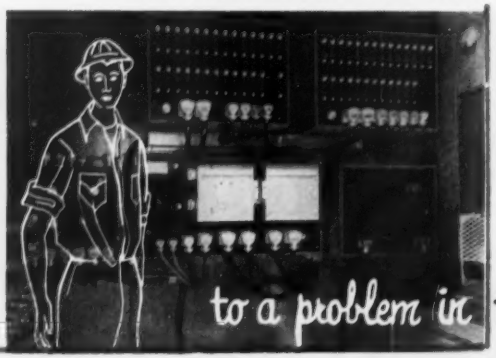

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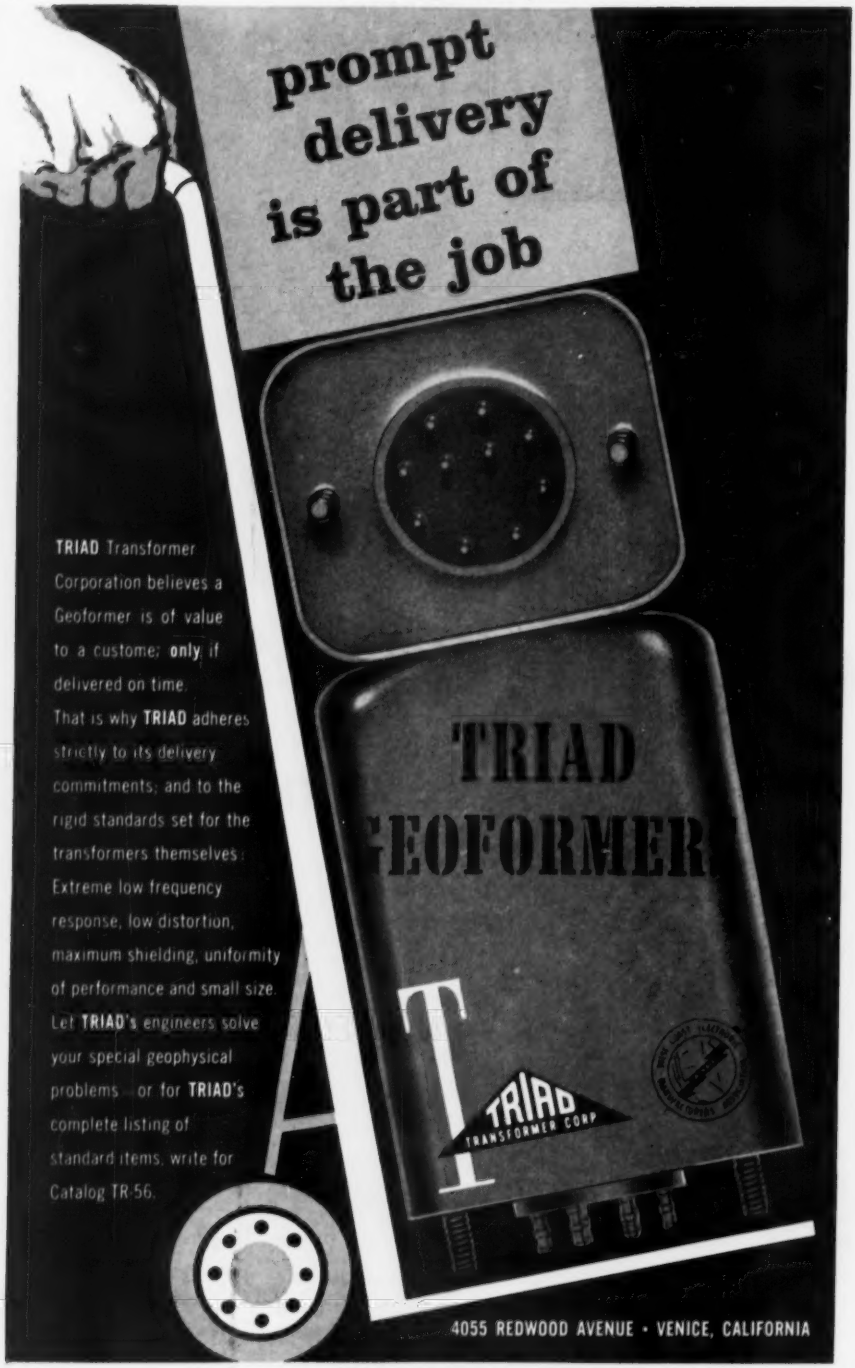
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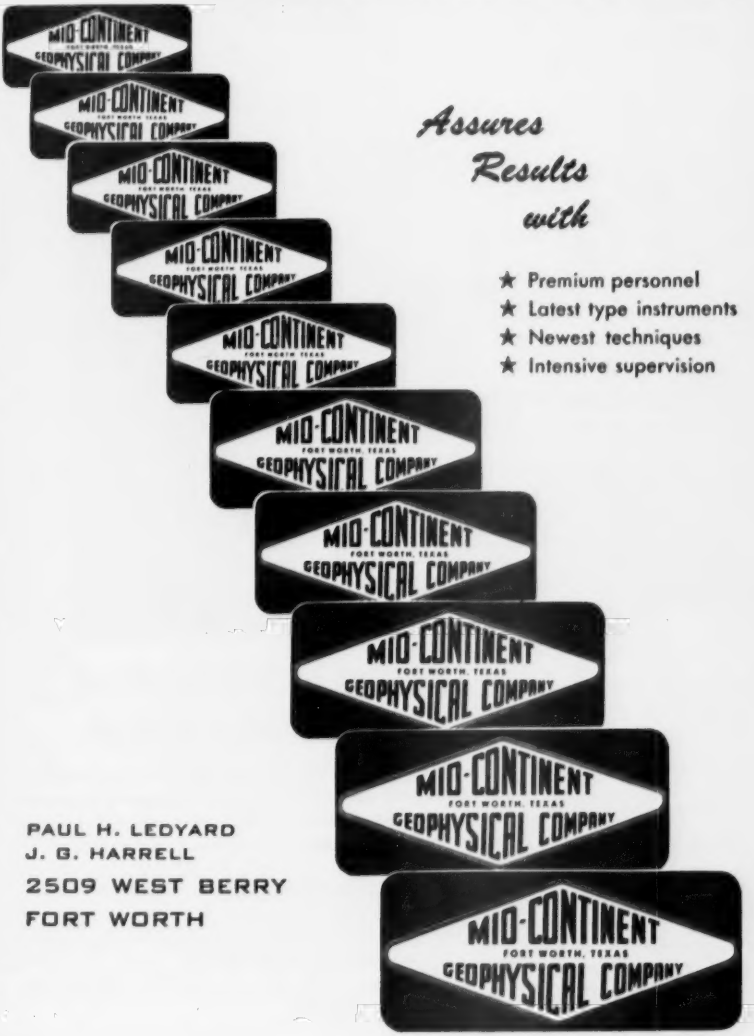

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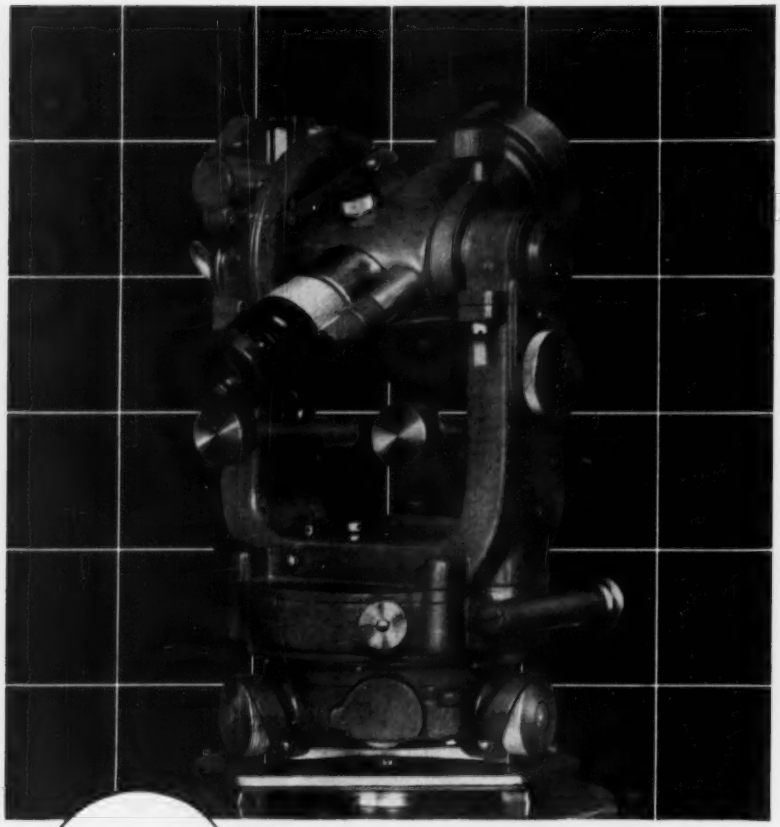

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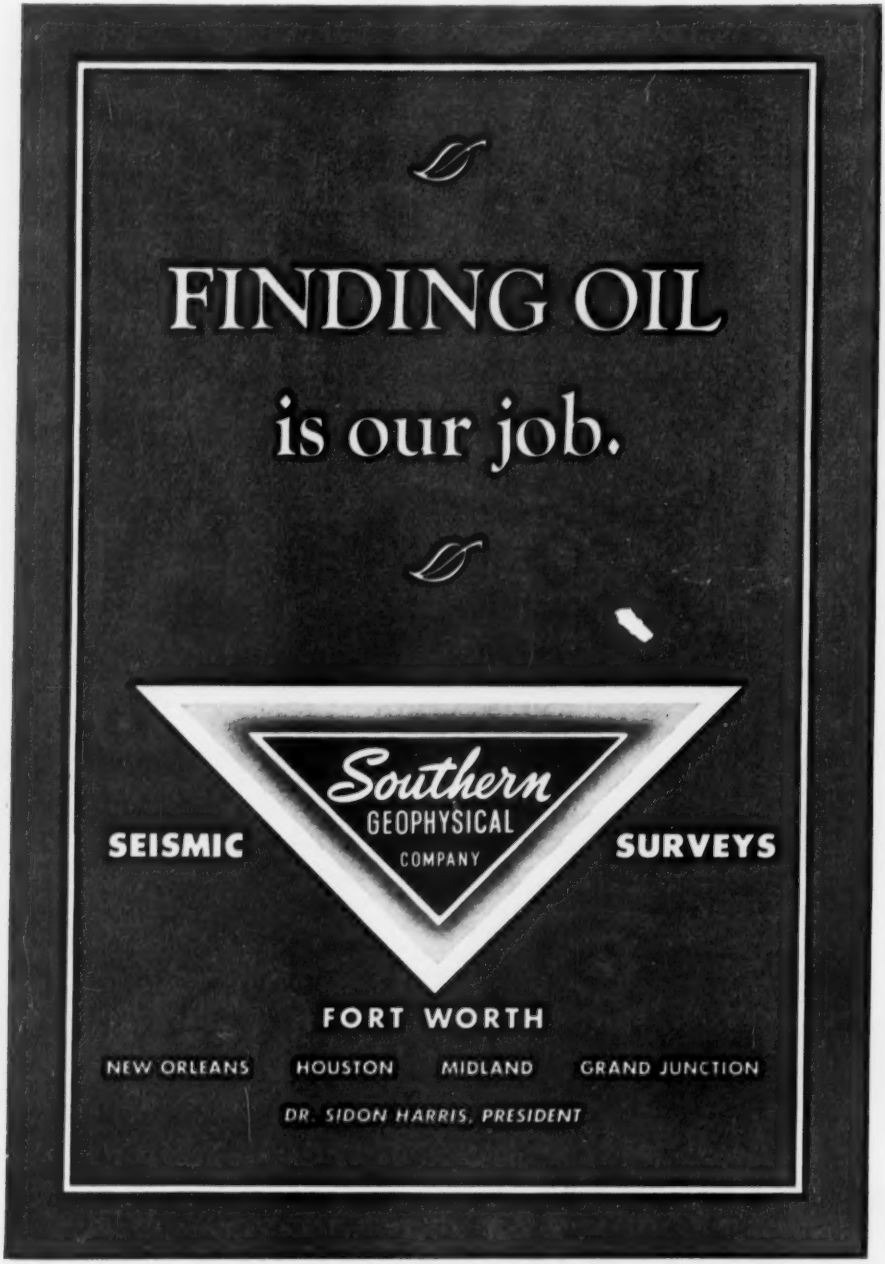
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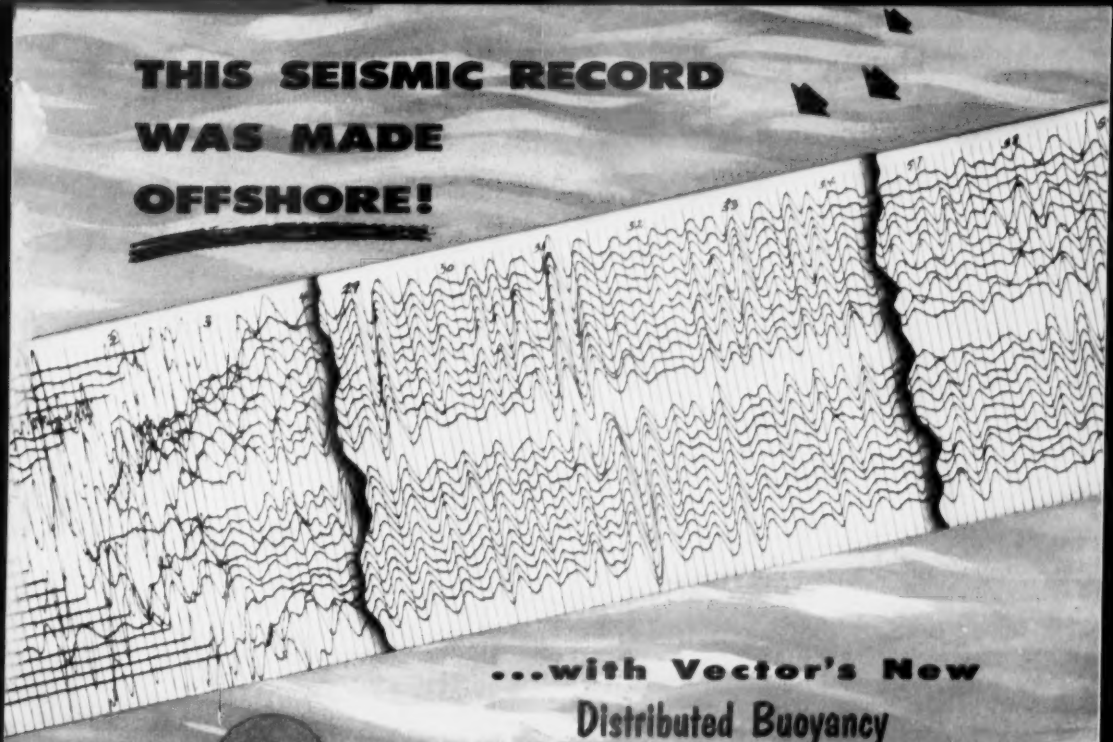

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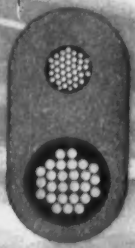
The low noise level seismogram pictured was recorded 15 miles offshore at a water depth of 40 feet. The new Vector floating cable used pressure sensitive geophones which were automatically positioned 10 feet below the surface when towing force was released.

Vector Distributed Buoyancy Cables have many other features that improve results and lower costs of offshore oil exploration — reduction of recorded noise level — elimination of cable damage and recording problems arising from bottom conditions — multiple geophones easily used. Other Distributed Buoyancy Cables are equally valuable in shallow water operations. Contact Vector for full information.



Vector Distributed Buoyancy Floating Cable is continuously extruded with a tough resilient jacket of almost indestructible buoyant polyethylene. The cable assembly and stress core are permanently bonded in the buoyant material.

The cable conductors are nylon insulated and jacketed in moisture proof neoprene which is oil filled to prevent water entry. Another example showing how Vector products are: *"Manufactured to Meet the Demands of Seismic Exploration"*

Vector MANUFACTURING COMPANY

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Here's one reason
VECTOR CABLES
are the strongest link
in the chain of
seismic operations

CONTINUOUS LOOP TAKEOUT CONSTRUCTION

Manufactured to Meet the Demands of Seismic Exploration

Vector Preformed Continuous Loop Takeouts help distribute strain along the entire length of the cable.

Pressure clamp secured contacts eliminate brittle solder-soaked leads and simplify maintenance.

To maintain production and reduce lost time, insist that your cables have Preformed Continuous Loop Takeouts.

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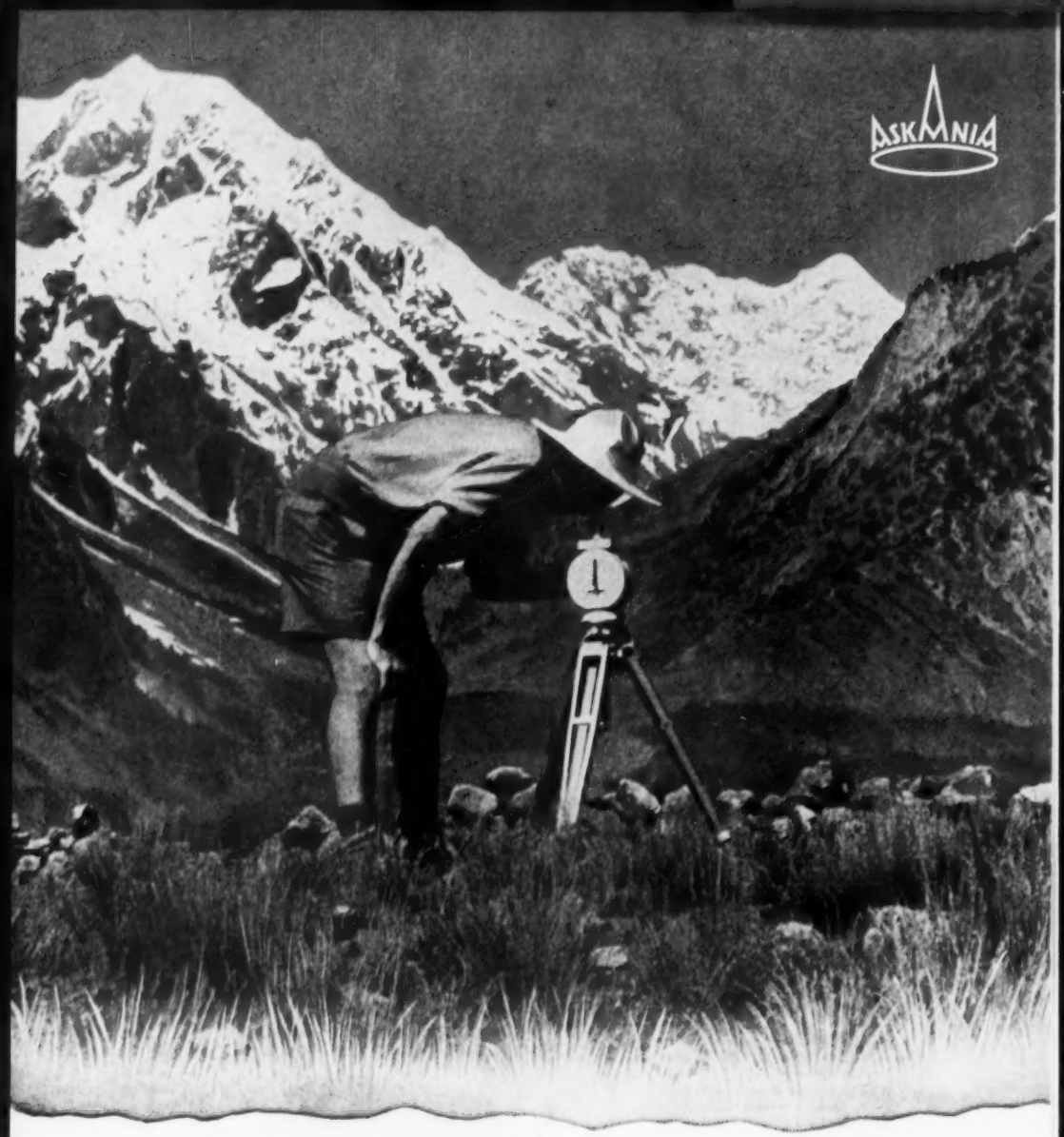

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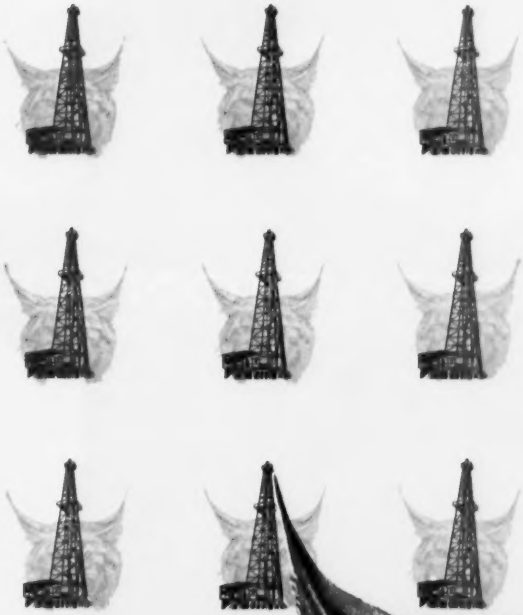

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9 out of every
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drilled are dry!

but that wildcat could be tamed with well planned and carefully executed exploration services. This record could be bettered at least 300% if adequate geological-geophysical information were obtained beforehand. For experience, and integrity in exploration call on the Republic Exploration Company.

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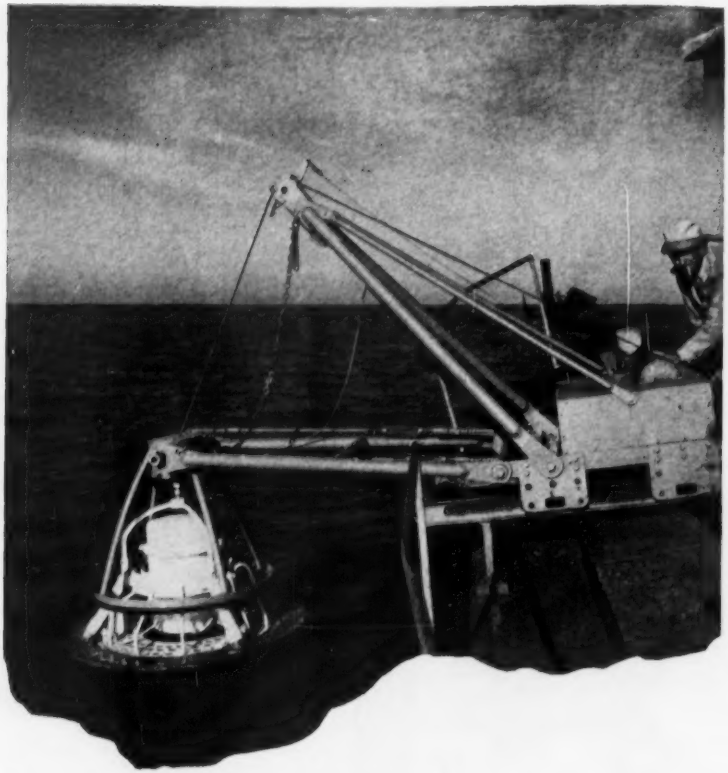

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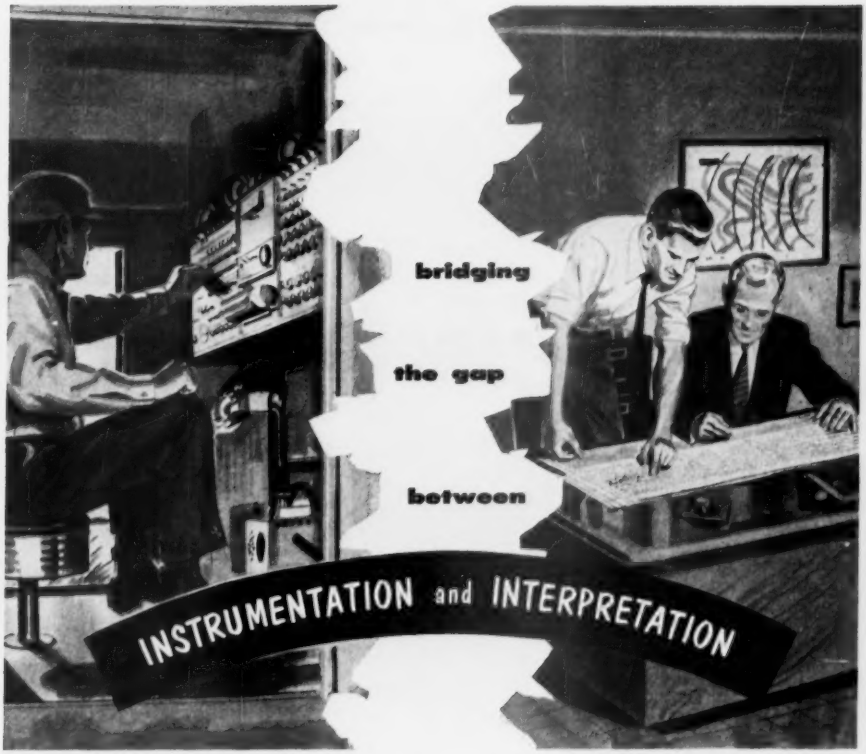

It is a known fact that geophysical instrumentation has advanced faster than geophysical interpretation. Due largely to the competitive efforts of specialized manufacturers, instrumentation has made significant strides in the past ten years. Whereas, interpretation has not kept pace.

Robert H. Ray Co. makes a concerted effort to remedy this inequity through progressive interpretive research. Men have been assigned to special projects devoted exclusively to such problems as velocities, migrations, and faults. Further, very close coordination with field parties is maintained at all times. Any interesting or peculiar interpretive problem encountered is referred directly to this research staff for review and study.

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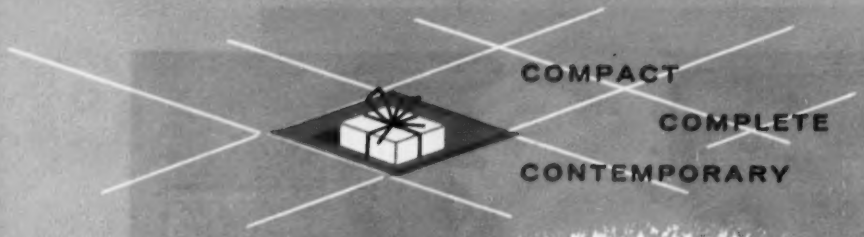

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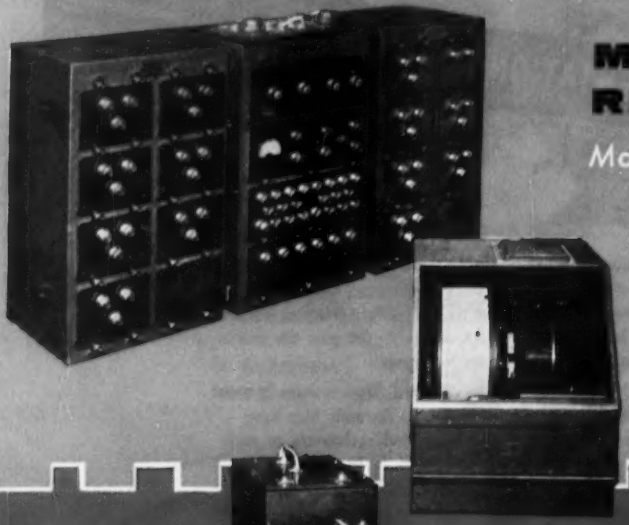

MAGNETIC RECORDER

Model FR-1 24 Channel

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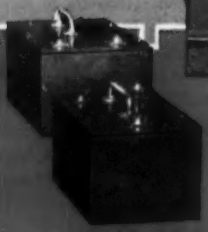

For the Geophysicist

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His Magnetic Tape Requirements

The FR-1 is a complete magnetic recording system utilizing pulse width modulation together with the latest concepts in geophysical amplifiers. The monitor record is obtained through an instantaneous dry process, precluding the need for dark room facilities.

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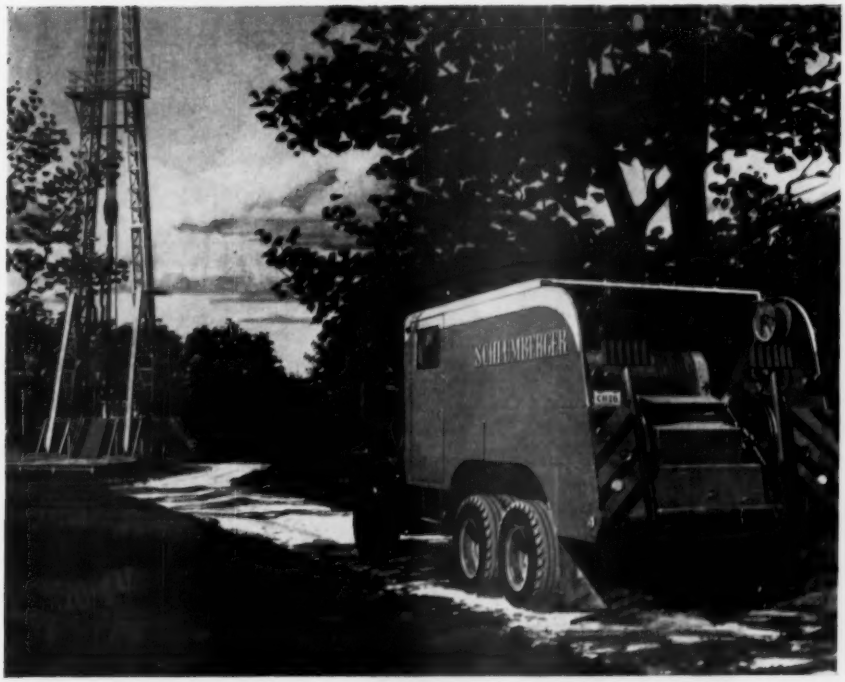

The blue and white color, yes, but its true distinction results from the variety of accurate well logging and perforating services it performs on one trip to your well. More than 20 years of field equipment engineering contribute to its dependability. The Schlumberger-designed equipment in the unit . . . the well-trained personnel who operate it . . . and the competent interpretation and log analysis you receive further distinguish the Schlumberger field unit from any other in the field.

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Designed in the Hercules Research Center after careful study of actual offshore requirements, these new, improved steel containers meet all prospecting requirements included in reflection and refraction shooting.

Hercules representatives welcome the opportunity to discuss with you how Vibronite-B packed in these modern containers can assist in your seismic work.

Technical Data

Vibronite-B is packed in distinctive, light blue containers of heavy-gauge steel to withstand transportation, handling, and storage conditions, and to prevent water and moisture penetration. They have a density greater than salt water, which eliminates all possibility of floating charges. These completely new containers are also equipped with large bails and recessed ends to facilitate loading and unloading in the holds of boats, and to provide convenient handling by shooting crews. Hercules Vibronite-B is now available in five container sizes: 8 inches by 50 pounds; 8 inches by 40 pounds; 5½ inches by 25 pounds; 4½ inches by 16⅔ pounds; and 4½ inches by 10 pounds.

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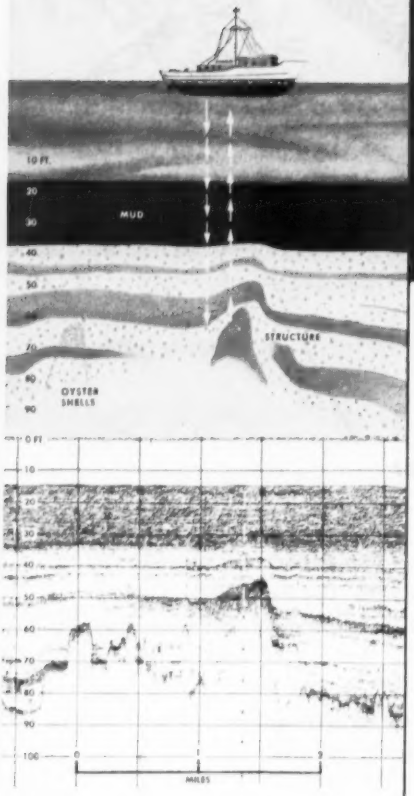

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Developed by Magnolia Petroleum Company

...to see beneath the bottom!

Geophysicists and foundation engineers working in offshore waters now have another technique at their disposal. Physicists at Magnolia's Field Research Laboratories have used the principles of underwater acoustics to develop the Marine Sonoprobe, a device which can map shallow sedimentary formations with remarkable accuracy. Costing a fraction of waterborne seismic work, a Marine Sonoprobe survey can penetrate as much as 100 to 200 feet beneath the sea bottom.

USE OF THE INSTRUMENT IS RECOMMENDED:

- For reconnaissance mapping before seismic work is begun.
- To complement the seismic work.
- For running profiles between core holes.
- To reveal tight folding conditions unsuspected by the seismograph.
- To reveal rock outcrops where coring can be done.
- As a primary tool for detailed mapping of sub-bottom sediments.
- Wherever accurate depth work is needed.

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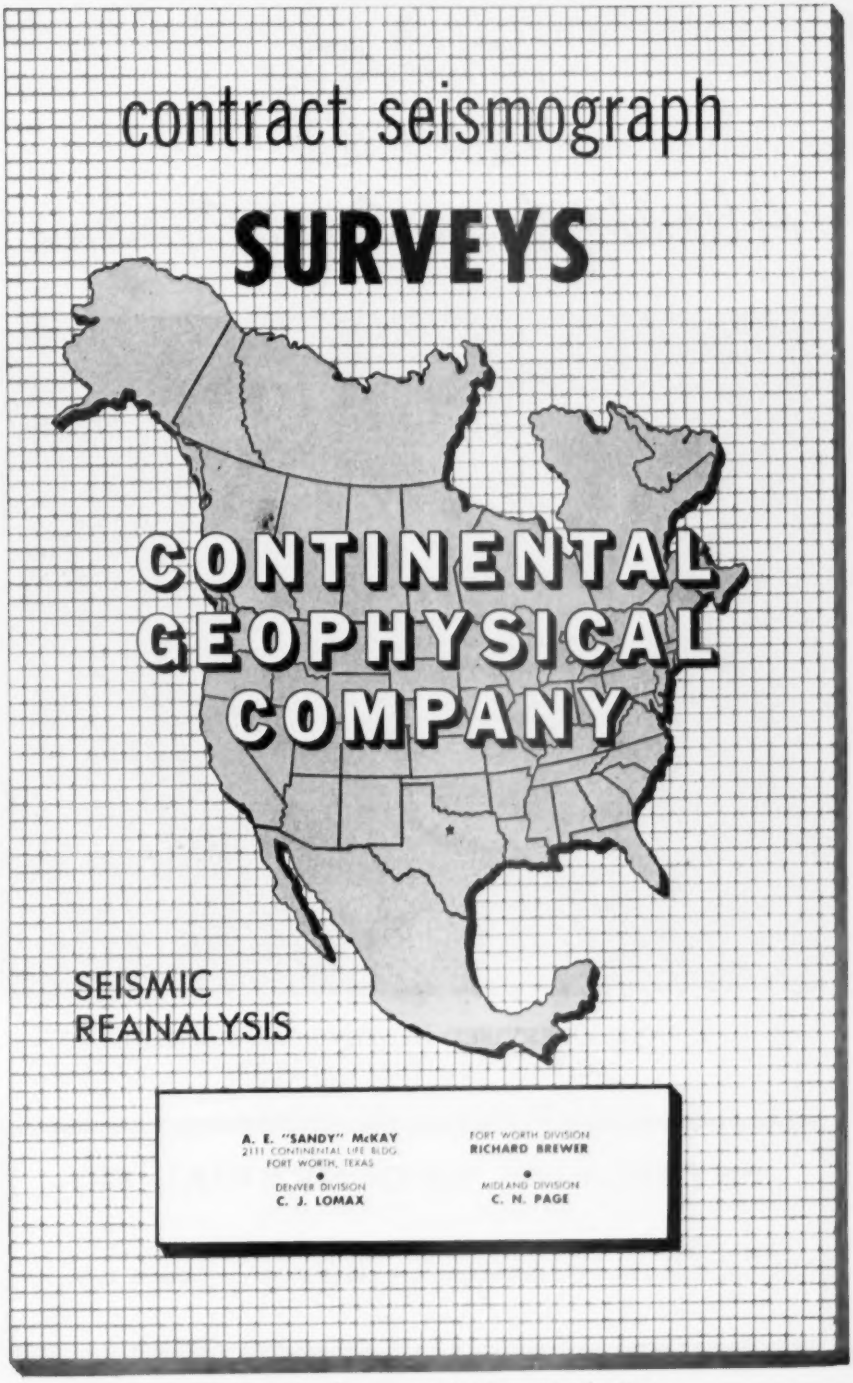
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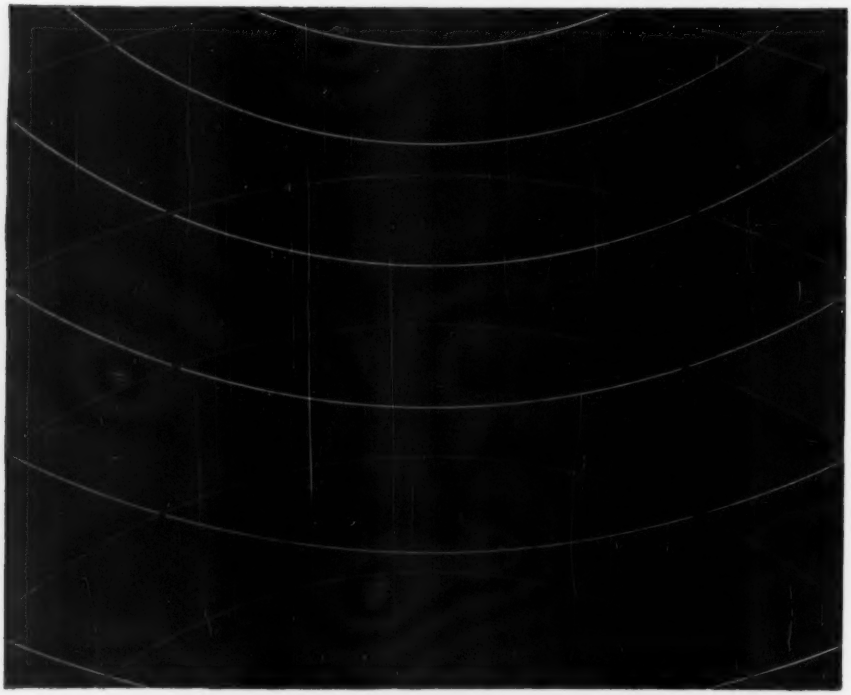

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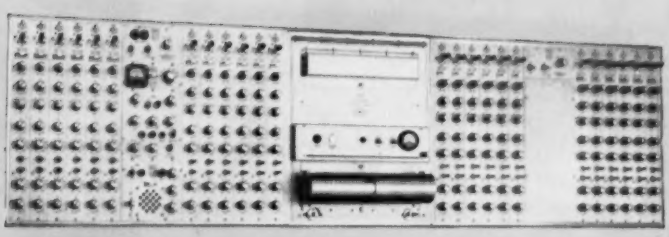

G-33 Full Spectrum
SEISMOGRAPH SYSTEM

SIE GA-33 Geophysical Amplifiers installed in an SIE G Series Seismograph System result in the widest range of recording applications ever offered the geophysical industry. In this small package are combined facilities for recording Refraction, Reflection, and High-Frequency seismic records . . . allowing the petroleum geophysicist to cover the entire seismic spectrum from 4 to 600 cycles-per-second with just one instrument.

Since the G-33 replaces three separate systems, it **cuts instrumentation costs in half!** In addition, SIE G-22A Seismograph Systems can be converted to Full-Spectrum operation simply by substituting plug-in GA-33 amplifiers and exchanging galvanometers . . . another example of SIE design forethought that lowers equipment costs for the industry's leading geophysical organizations.

ESSENTIAL TO A COMPLETE GEOPHYSICAL PROGRAM

Although SIE G-33 equipment exceeds any other seismograph in its capabilities and range of applications, it occupies only half the space required by many conventional single purpose instruments. With adaptability to every seismic exploration method, outstanding operating flexibility, and maximum field utility in terms of size and weight, the G-33 Full-Spectrum Seismograph System meets every requirement of modern exploration programs.

The GA-33 Geophysical Amplifier features Full-Spectrum filtering, variable AGC time-constants, and extremely low distortion (less than 1%). Its wide range is especially useful in magnetic recording applications, while plug-in construction permits simple installation and easy maintenance.

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MAGNETIC RECORDING SYSTEMS

The impact of magnetically recorded wide-band seismic information has been met at SIE by the most intensive research and development program in the company's history. Co-operating with geophysicists and engineers active in every phase of petroleum and electronic instrumentation, SIE has evolved the MR series of magnetic recorders together with auxiliary equipment and two new wide-band seismograph systems, the G-22A, and G-33. In addition, custom designed magnetic recording equipment has been produced to meet special requirements of several large geophysical organizations.

In magnetic recording instrumentation as in conventional seismograph manufacture SIE equipment continues to set,

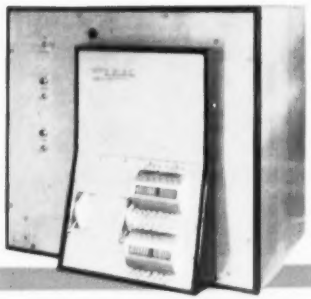
The Standard of the Industry

MR-4 MAGNETIC RECORDER

. . . features outstanding versatility and reliability Signal-to-noise ratio in excess of 60 db, wide frequency range, and extremely low distortion suit the MR-4 for every field recording application.

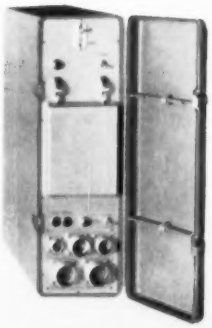
MR-5 MAGNETIC RECORDER

. . . can be used for more complex field recording, and is especially useful in laboratory analysis. Twin tape transport and individual head positioning controls allow recordings to be composited for noise integration and other interpretation techniques.



PMR-6 PORTABLE MAGNETIC RECORDER

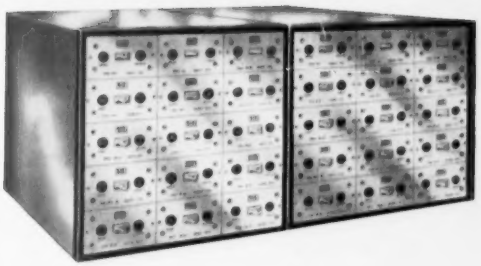
. . . can be used in areas completely inaccessible to vehicle mounted systems. Weighing only 43 pounds, the PMR-6 uses the same recording tape as the MR-4 and MR-5 and is easily carried by one man.



and LABORATORY ANALYSIS SYSTEMS

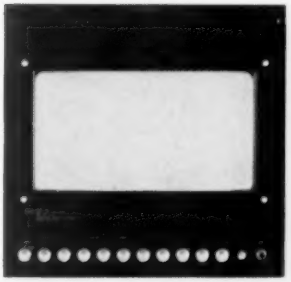
SIE auxiliary equipment for magnetic recording includes specially designed units and modifications for various field and laboratory techniques. Direct viewing equipment which allows records to be examined in the field with MR-4 and MR-5 Recorders, is one example. Recorders are available with or without frequency modulation equipment; the noise reducing SIE Length-Time Servo System; and moveable recording heads, thus permitting the selection of a system tailor made for every application at lower cost.

In the laboratory, the SIE Normal Move-Out Remover is one example of the specialized analysis equipment available. Development and research on other magnetic recording devices is a continuous process at SIE. When planning any phase of a wide-band instrumentation program, be sure to call for information on the latest SIE developments.



MODULATOR — DEMODULATORS

. . . for frequency modulation recording are housed in two cases for vehicle installation. Using the SIE Slope Modulator which provides an extremely high deviation ratio, the Units feature very low distortion—less than 1%.



MO MULTI-CHANNEL OSCILLOSCOPE

. . . allows laboratory presentation of an entire magnetic recording. Twenty-four channels are portrayed with timing lines, thus permitting records to be examined rapidly during interpretation and when compositing and filtering.

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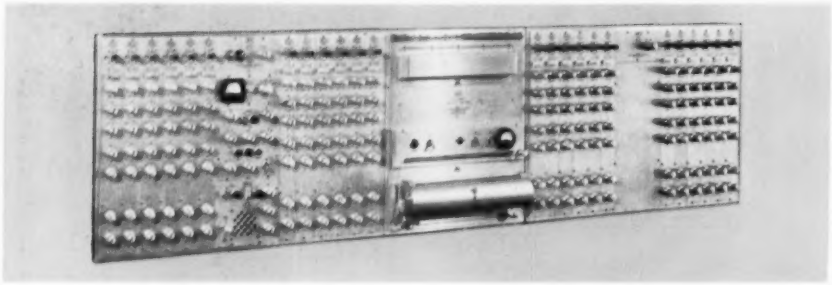
G-22A

SEISMOGRAPH SYSTEM



for high-production Operations

FREQUENCY RESPONSE: Within 3 db from 10 to 500 cps. Filtering as specified.

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AGC CONTROL RANGE: 0.5 microvolt to 0.1 volt input. (Three time-constants selected from front panel.)

GAIN CONTROL CIRCUITS: AGC, Expander, or simultaneous AGC-Expander operation.

RECORD PRESENTATION: Single record. Dual output. Dual record.

- First-Arrivals Unfiltered.
- Individual Channel Paralleling and Testing Switches.
- Simplified Controls.

Features essential to high-speed operation — available only on special order in many systems — are standard equipment in the G-22A.

New circuitry provides unmatched performance with all recording methods while simplifying matching and operating procedures.

AGC Time-Constants, mixing method and percentage, and type of record presentation can be selected from the front panel. Two attenuation rates on both high and low cut filters provide hundreds of filtering combinations.

From the new self-biased AGC circuit to the simplified control panel, the G-22A's "field engineered" design combines practical operation with high flexibility.

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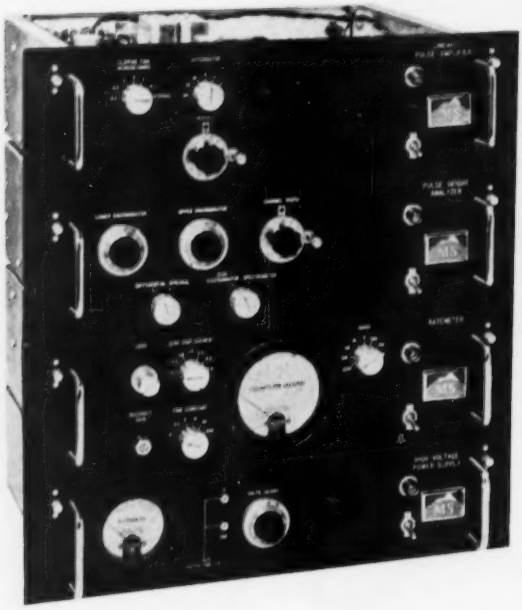

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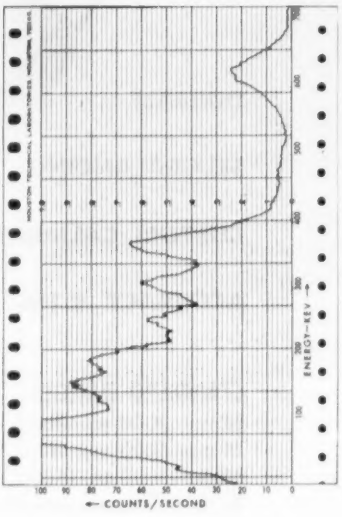

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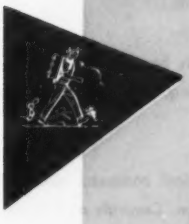

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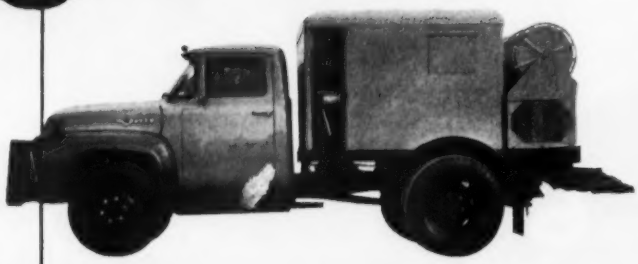

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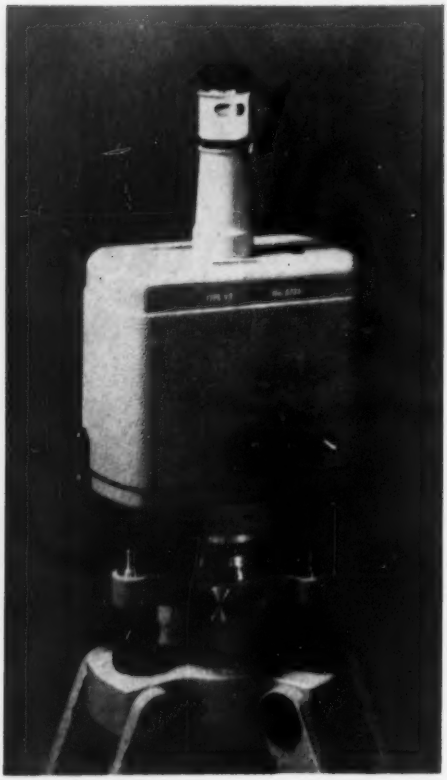

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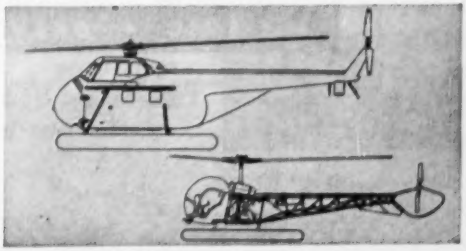

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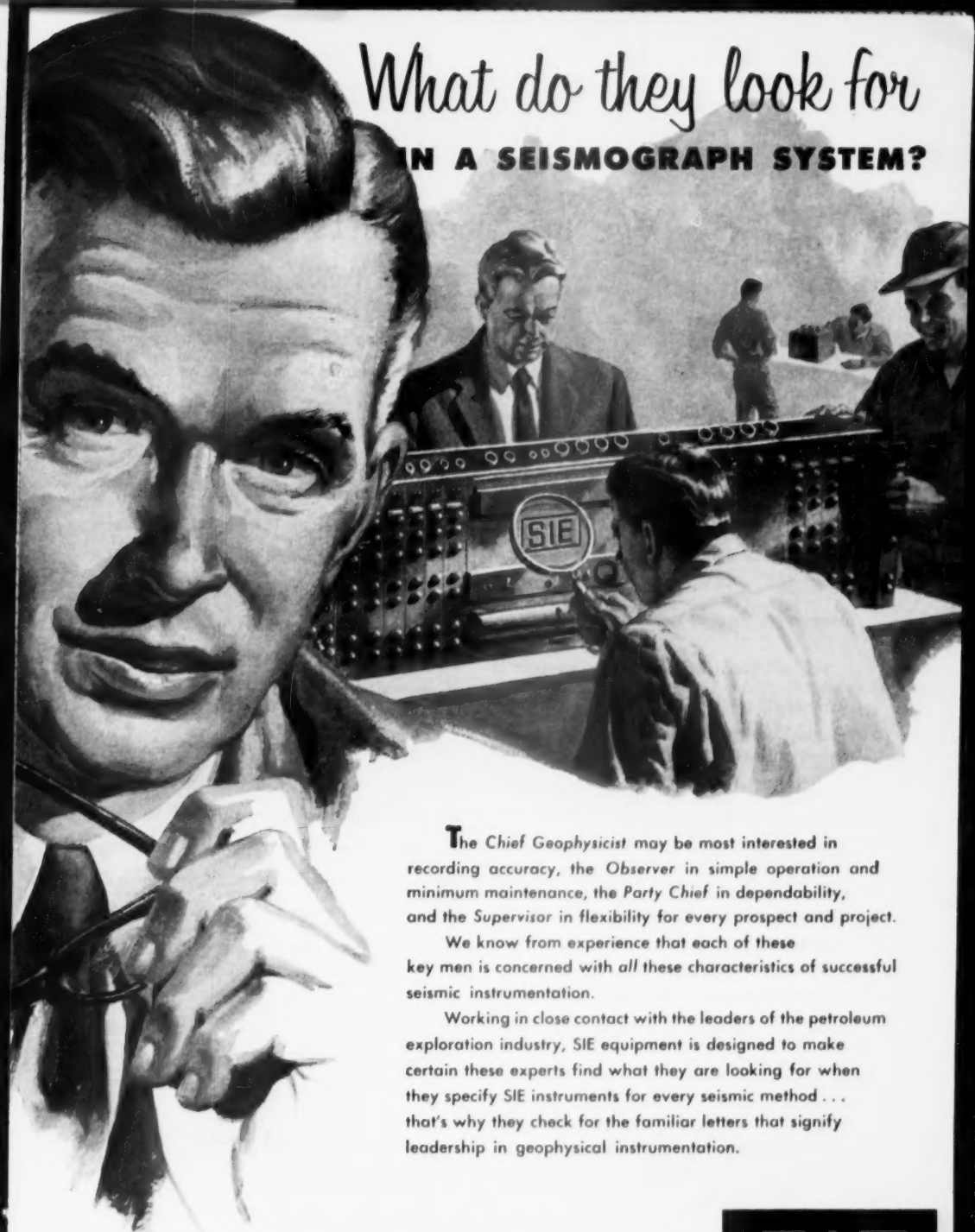

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We will begin with a problem involved in getting the data corrected for what we already know.

Unfortunately the gravity meter is a very sensitive measurer of elevation. Pick the instrument up, set it on a box a foot high and it tells us in no uncertain terms that we have moved away from the center of the earth by 0.0000048%!

If elevation relief is connected with oil structures, that should be a separate study, so this effect must go.

In correcting our data for elevation, which has been measured by the transit, we assume that the station is on a nice flat plain*, instead of a box.

This correction is easy if we know the density of the surface materials. There is the joker. We make some guesses and if the work looks like the local gravity highs are on topographic highs, or vice versa, we guess again. This gets to be a lot of calculating unless your data are on punched cards**.

As a final check, we have been running cross-correlations of residual gravity values with their respective elevation***. If several hundred stations are involved, this seems to give a reliable and useful index of the accuracy of the elevation factor or how much to change it. We think it works pretty well.

* more on this next time
** ours are
*** don't try this with a desk calculator

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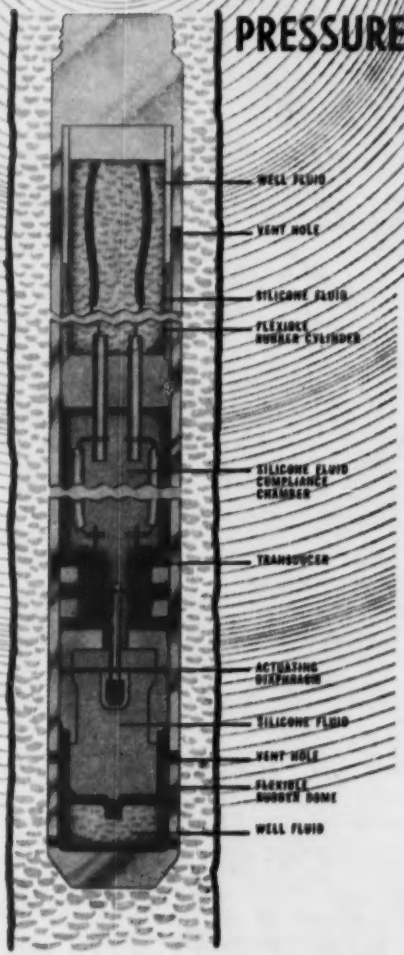

The GCE Pressure Sensitive Well Geophone is designed for conducting accurate velocity surveys. This design for a specific application meets all of the requirements for well shooting surveys.

The GCE is a pressure sensitive instrument with a much higher sensitivity than the ordinary velocity type well geophone. It is relatively insensitive to case motion, less susceptible to cable noise and thus the signal-to-noise ratio is appreciably increased. This permits shots to be taken immediately after stopping the cable.

A preamplifier is not necessary with the GCE Well Geophone, due to the instrument's high output and low impedance. The transducing element is of the variable reluctance type.

The unit will withstand 10,000 pounds of hydrostatic pressure. Pressure equalization allows its use at any depth.

The GCE Well Geophone was designed by Gulf Research and Development Company, and is licensed to SSC for manufacture, sale or lease.

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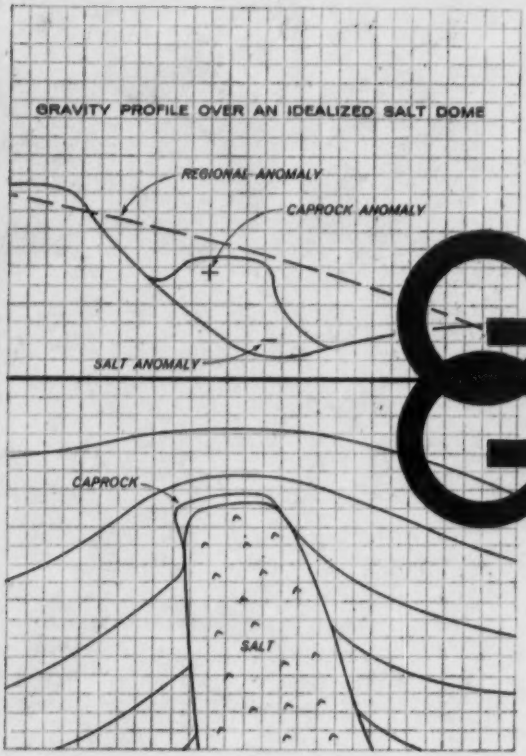

GRAVITY & GEOLOGY

This diagram illustrates a gravity profile over an idealized salt dome. The salt, being of lesser density than the surrounding strata, produces a negative anomaly; the very dense caprock produces a positive anomaly.

By integrating all available information on local geology with *detailed* gravity data, GSI can utilize gravity surveys as a tool for solving your *specific* subsurface problems. GSI gravity interpretation reports are made available on a *current* basis...providing the information you need to make immediate decisions affecting your exploration program.

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